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PALEOECOLOGY AS CONTEXTUAL ARCHAEOLOGY: HUMAN VIABILITY OF THE LATE QUATERNARY ICE-FREE CORRIDOR, ALBERTA, CANADA

BY

CAROLE STEIN MANDRYK

A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
AND RESEARCH IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF ANTHROPOLOGY

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ABSTRACT

The traditional focus on the question of the ice-free corridor's existence overshadowed considerations of environmental viability. This study demonstrates the necessity of including biological and social viability of the environment in the analysis of the role the corridor played in the peopling of the New World. The theoretical and historical context within which the concept and analysis of the ice-free corridor developed is critically reviewed.

Stratigraphic pollen analysis was done on sediment cores from three sites in the upper North Saskatchewan drainage basin. Radiocarbon AMS dates provide a chronology back to 17,960 B.P. Reconstruction and interpretation of the local pollen zones included a reevaluation of steppe and grassland as analogues for full- and late-glacial vegetation. Analysis of modern steppe and grassland pollen spectra demonstrate that *Artemisia*:Gramineae ratios distinguish between the two vegetation types. Full-glacial regional vegetation (18,000-16,000 B.P.) is interpreted as a cold semiarid *Artemisia* steppe, late-glacial (16,000-12,000 B.P.) as a *Artemisia-Betula* shrubland, and post-glacial (12,000-10,000 B.P.) as a *Picea* woodland - *Artemisia-Populus* steppe parkland mosaic.

Full-glacial physical environments were characterized by extremely cold, arid, and windy periglacial conditions. Due to the effects of abrupt deglaciation, late- and post-glacial physical environments were dominated by chaotic ice-stagnation environments. The estimated effects of ice-stagnation processes on Albertan landscapes are presented for 18,000, 14,000, 13,000, 12,000, 11,000, and 10,000 B.P.

General qualitative comparison of high latitude occupation during the last glacial maximum revealed a correlation between extremely depauperate environments and a lack of human occupation. Analysis of general principles of hunter-gatherer adaptations applicability in marginal environments suggests submarginal environments are nonviable because of the incompatibility of meeting both economic and social needs within the constraints of an extremely depauperate environment.

In specific quantitative testing of the study area, calculations of harvestable primary production, prey biomass, and optimum yield available to humans are shown to be below the minimum nutritional needs of a socially viable population in the linearly constricted environment of the corridor from 18,000 to 13,000 B.P. Implications of the non-viability of the corridor prior to 12,000 ya B.P. are discussed.

PREFACE

Several years ago I worked on an archaeological site where I was continually frustrated by a lack of adequate consideration of the matrix from which the artifacts and faunal remains were being extracted. I was also aware of my inability to provide that necessary consideration. In a very real sense, everything in my academic career since then, and everything in this dissertation follows from my search for meaning in context.

Items, facts, and ideas have little meaning unless seen and interpreted within their proper context. This dissertation provides that context for the analysis and understanding of potential or actual hunter-gatherer adaptations in the late Quaternary ice-free corridor of western Alberta and contributes to an understanding of the role the corridor may have played in the peopling of the New World.

ACKNOWLEDGEMENTS

For numerous discussions and advice I thank my supervisor Dr. Charles E. (Charlie) Schweger and the other members of the committee: Dr. Alan Bryan and Dr. Clifford Hickey (Department of Anthropology), Dr. Michael Hickman (Department of Botany), and Dr. Nathaniel Rutter (Department of Geology) of the University of Alberta, and Dr. Dena Dincauze (Department of Anthropology) of the University of Massachusetts. In particular I would like to thank Charlie for years of valuable direction, encouragement and "centering", both professional and personal, as well as for use of the Paleoenvironmental Laboratory, Department of Anthropology, University of Alberta. I thank Dr. Michael Hickman for providing cold storage space for lake cores in the Biological Sciences Building, University of Alberta, along with technical assistance for the analysis of lake core sediments, and Dr. Alan Bryan for constructive editorial advice that went well beyond the call of duty.

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For verifying preliminary identifications of *Sphaerium* and *Psidium* mollusca I thank J. Van Es, Department of Zoology, University of Alberta.

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1. Introduction

1.1 Objectives

One of the most contentious issues in American archaeology concerns the timing and route of the initial peopling of the New World. The arguments most commonly include consideration of the "ice-free corridor," a presumably unglaciated region between the Wisconsinan Laurentide and Cordilleran ice masses. Although the traditional focus on the question of the corridor's existence has long overshadowed considerations of environmental viability within the corridor, environment is in fact the critical determining factor in consideration of what role the corridor could have played in the peopling of the New World. Given that "environmental production sets upper limits to the human food base" (Belovsky 1988:340), my goal is to establish whether upper limits of the potential human food base of the ice-free corridor were in fact below the minimum required to maintain a biologically and socially viable human population.

Consequently, the purpose of this work is to:

1) establish the theoretical and historical context within which the concept and analysis of the ice-free corridor have developed;

2) develop a paleoecology of a region in the ice-free corridor of west central Alberta at the ecosystem level, including abiotic and biotic characteristics and processes, thus establishing physical context;

3) test the region's viability as a human environment through the analysis of relationships between the physical environment and social and biological factors; and

4) examine the implications of the reconstructed region for the corridor's role in the peopling of the New World.

1.2 Previous Work

Other than previous geological research in the corridor area, which will be dealt with extensively in Chapters 2 and 6, little of the previous work done in the corridor deals directly with the issues of interest to this study. Only Zutter (1987:1) focused on comparable objectives while modeling the vegetation, biomass, and usable resources available to late- and post-glacial inhabitants of the ice-free corridor; and evaluating the model in terms of optimal foraging strategies.

Aside from geological concerns, much of the previous work on the corridor itself or within the vicinity of the corridor dealt exclusively with either archaeological or paleoecological issues. Paleoecological work in Alberta dates back twenty years, although most of the work has been done in the last decade. Due to a lack of deep basins, preservation problems, and dating difficulties, most studied sites date to late post-glacial times. Sites once thought to contain records dating earlier than 11,000 years ago (e.g., Mott and Jackson 1982) are commonly revealed to have dating errors. As a result, Alberta has a fairly depauperate Quaternary paleoecological record thus far.

The history of the theoretical background of archaeological research in the ice-free corridor is dealt with in Chapter 2. It should be noted that despite four decades of professional archaeological activity in Alberta, few *in situ* Paleoindian sites have in fact been located (Ives, Beaudoin, and Magne 1989:14). Of those that have been identified, none date to the period of interest in this study; i.e., 18,000 to 11,000 years ago. The sites of Vermillion Lakes (Fedje 1986; 1987), Sibbald Creek (Gryba 1983), Charlie Lake (Fladmark et al. 1988), and Pink Mountain (I.Wilson 1986: 1987), are commonly mentioned in discussions of the earliest archaeological sites in the ice-free corridor. Only Charlie Lake, in east central British Columbia, and Vermillion Lakes, near Banff, Alberta, produced well stratified, reliably dated contexts, with dates of 10,700 years B.P. (Fladmark et al. 1988) and 10,400 years B.P. (Fedje 1986) respectively. Thus the oldest documented human occupation in the corridor region dates to the late post-glacial, by which time the issue of the ice-free corridor is largely irrelevant.

1.3 Theoretical Approach

The objectives as stated can best be met by dealing with a region as the analytic universe, as it is preferable to examine both paleoecological reconstructions and human adaptive behavior from a regional perspective (Johnson 1977:479; Dincauze 1981:55; Soffer 1985:15). Paleoenvironmental reconstruction typically involves areas larger than sites, the traditional focus of archaeological investigation. Ideally, such reconstruction results in a "description of change in the physical and biological contexts of human existence" (Dincauze 1987:255), contexts that are more fruitfully seen at a regional level. In other words, it is inherent in the analysis of paleoenvironmental conditions to operate "at the regional scale, the larger context in which the site was embedded" (Dincauze 1987:301).

Even if the limitations of paleoenvironmental reconstruction did not constrain the spatial scale of analysis, arguments could still be made for the utility of a regional approach. In addition to recognition of variation in environmental conditions, a regional framework of analysis and interpretation gives a spatial context for the examination of variation in past human behavior (Gamble 1986:255). As human behavior is adapted not to the site but to the region, a region "therefore is the appropriate unit of analysis" (Gamble 1986:62).

There are considerable differences in how the "regional approach" is defined or conceptualized. Binford (1964, cited in White 1985) suggested that it was the most appropriate method for the study of cultural process, essentially focusing on variation through time, albeit on a regional scale. More recently, borrowing of concepts from geography has resulted in a focus on spatial variation. Keegan and Diamond (1987:81) discuss the usefulness of biogeographic principles for archaeological analysis of spatial distributions and pattern recognition. Savage (1990a, 1990b) extols the virtues of "landscape archaeology," which he defines as an integrative paradigm for the study of the spatial relationships between past human systems and their environments.

Marquardt and Crumley (1987:13) further point out that the concept of region itself is dynamic, varying on different spatial and temporal scales, as does the human behavior within such regions. Thus we return to the concept of archaeological context and the importance of understanding the environmental matrix within which human cultural systems are embedded, however variable that matrix is. The regional approach allows for the recognition and analysis of patterns at larger scales, both temporal and spatial, in the study of the physical, biological and social environments that form the contextual matrix for human cultural behavior.

The principles of ecological anthropology provide the theoretical base for the regional approach. First of all, ecological anthropology, along with the regional approach, has as its primary focus the context within which human adaptation takes place (Moran 1990); that is, the ecosystem provides a conceptual framework for the modeling of human behavior (Butzer 1990:94; Greiser 1985:5).

Moran (1982) describes ecological anthropology as an interdisciplinary approach to the problems or constraints posed by human habitats. Ecological analysis seeks to discover and understand possible causal relations between covariation of environmental and cultural phenomena (Watson, Le Blanc, and Redman 1984:154). With its goal of understanding how human cultural systems deal with environmental problems, it is clearly an intellectual descendant of Steward's (1955) cultural ecology, which dealt with the relations between environmental resources and human behavior (Moran 1982:43).

Modern ecological anthropology has as one goal the identification of limiting factors and selection pressures of the environment and their effect on human adaptation (Davis 1990:274; Gamble 1984:238). An underlying assumption is that human behavior is constrained by the environment (Halstead and O'Shea 1989:2); that is, despite culture, "humans must solve the same ecological problems as all other organisms" (Low 1990:236), and variations in the environmentally determined distributions of biotic and abiotic resources will determine certain aspects of human behavior (King and Graham 1981:128). Minc and Smith (1989), for example, demonstrated a correspondence between environmental factors and observed patterning in the prehistoric archaeological record of Alaska.

This is not, as some might argue, environmental determinism or even possibilism, but instead a type of "probabilism," which argues that humans do have freedom of choice but only within the confines set by the environment; "physical conditions determine probable courses of action, but the ultimate decision is left with man's own will" (Whynne-Hammond 1985:6). Leach (1973:764) suggests that "the proper analogy for human behavior is . . . a game of chess. The field of play and the rules of the game are laid out in advance but the way the game is played out is unpredictable."

The second focus of ecological anthropology is on dynamic spatial-temporal environmental variability (Jochim 1990:77). Archaeologists often feel that a description of the environment in which a site is found fulfills criteria for doing ecological archaeology (Dincauze 1987:290). They are, however, ignoring the dynamic spatial-temporal variability of the environment that is particularly characteristic of the Quaternary, in which instability and "variable and discontinuous rates of change" (Dincauze 1981:78) are the norm. Implicit in understanding the functioning of an ecosystem is an appreciation for the dynamic nature of the relations between cultural, biological, and physical processes. Humans are part of the ecosystem (Moran 1982:54). They do not simply use it or live on it; they interact dynamically within it.

The third focus of ecological anthropology is in some ways a lack of focus, in its resistance to concentrating on a single factor, e.g., environment or culture as privileged in explanation (Moran 1990); but instead stressing the "complex links of mutual causality" (Moran 1990:24). Ideally, ecological anthropology leaves behind a preoccupation with single factor explanations, refusing to see either biophysical environment or culture as a prime mover (Milton 1984). Instead it focuses on a variety of interacting factors, of "multivarious strands woven together in the interplay of cultural with environmental systems" (Gamble 1986:60). As Soffer (1985:352) argues, looking for the critical component essentially oversimplifies the problems of human adaptation.

Implementing a multivariate approach to causality can be demanding, in its insistence that "relations among multiple variables must be examined simultaneously" (Jochim 1990:76). The concept of "heterarchy" can serve as a unifying operational principle. Heterarchy, as opposed to the more familiar concept of hierarchy,

> denotes a structural condition in which elements have 'the potential of being unranked (relative to other elements) or ranked in a number of ways, depending on systemic requirements' (Crumley, 1979; Marquardt and Crumley, 1987). In contrast, hierarchical structure is one in which some elements, on the basis of certain factors, are in the condition of being ranked subordinate to others (Crumley and Marquardt 1990:74).

Furthermore, Crumley and Marquardt (1990:75)

> contend that a common error, not just in settlement archaeology but in ecology, biology, and elsewhere, is that researchers uncritically 'nest' levels of analysis. While hierarchical structures are of considerable utility in the organization of data at a variety of scales, the researcher risks forgetting that hierarchy is an analytical strategy imposed on the heterarchical face of nature. These hierarchical links, whether programmed or conceptual or both, bias analysis and render inoperable a dynamic concept of region in which it is quite possible (perhaps even probable) that events which occur at 'subordinate' levels have major systemic shifts.

Thus the ultimate value of the concept of heterarchy lies in the attention it draws to the natural, multidimensional fluctuations in importance of elements that occur in dynamic systems.

1.4 The Problem: Myth vs. Reality

The meaning of the phrase "ice-free corridor" has varied considerably since the concept was first discussed nearly 60 years ago. An understanding of the history of the concept of the corridor can help elucidate the confusion and misunderstandings of the corridor that still exist today.

The original concept of the ice-free corridor was proposed in the 1930s as a reasonable response to questions concerning the Old World origins of the Folsom culture. As originally formulated, the ice-free corridor was a deglaciation corridor, by definition forming with the final retreat of the Late

Wisconsinan Laurentide and Cordilleran ice sheets. The idea subsequently was widely accepted both within anthropology and the popular press, being immortalized in MacGowan's 1950 text on early man, which unfortunately was written before widespread ^{14}C dating, and the consequent chronological corrections that followed. When the implications of the new dates were realized it became clear that a deglaciation corridor (then estimated to have opened ca. 8,000 to 11,000 years ago) was too recent to have been utilized as the route of the first North Americans. Nonetheless the idea did not really die, as "when there is a shift of paradigm the principal upholders of an established orthodoxy never change their views" (Leach 1973:762).

The deglaciation ice-free corridor was reincarnated as a Late Wisconsinan maximum ice-free corridor whose existence would "explain" the patterning of Paleoindian sites on the plains. The existence of the ice-free corridor was widely assumed to be fact in spite of accumulating evidence to the contrary. It had become a myth that was almost universally believed in, running "through the minds of many archaeologists, like a highway beckoning Paleoindians south from Beringia" (Fladmark 1986:15). The prominence of the corridor as a concept can be partly explained by unsubstantiated speculation and the acceptance of bad logic by archaeologists. "It is characteristic of archaeological logic . . . that basic assumptions remain unexamined, that data are confused with evidence, and that linking arguments are poorly developed" (Dincauze 1984:290). Arguments often go directly from observation to interpretation without bothering with analysis of data: e.g., "there was an ice-free corridor . . . humans could have passed through it . . . therefore they did."

The widespread belief in the corridor was abetted by confusion among archaeologists of the difference between possibility and demonstration. Several supporters of the ice-free corridor unwittingly utilized the possibilist fallacy, which is attempting to demonstrate that a statement is true or false by establishing the possibility of its truth, "when 'it could be' is followed by an unearned 'therefore it is" (Dincauze 1984:292). And as with any *post hoc* interpretation, once they "were offered and judged 'probable' or plausible they frequently became conventions . . . Gradually a myth was built up about the past. The myth consisted of inferences drawn from unevaluated premises and its *very scale of acceptance* gradually became further justification for belief in the myth" (Binford 1981:32, italics mine). This is an illustration of a phenomenon Said (1978:22) calls 'strategic formation' in which "groups of texts, types of tests, even textual genres, acquire mass, density, and referential power among themselves and thereafter in the culture at large." In support of this point, Olsen (1990:20), argues that "archaeological texts create not only knowledge of the past but the very reality they intend to describe." This confusion between description and creation contributes to the acceptance of unproven concepts and myth-building.

Archaeologists commonly see the scale of acceptance of an idea as support for that idea, as if the greater the numbers of archaeologists who believe in a concept, the more valid that concept is. "For some American archaeologists, apparently, the weight of claims is equal to the weight of evidence, regardless of the quality of each individual claim" (Beaton 1991:212). Adams (1973), credits this attitude to the lack of mathematical training in archaeology. Archaeologists often "seem to believe that the probability of a whole string of assumptions being true is equal to the sum, rather than the product, of their individual probabilities" (Adams 1973:27);

whereas, "the multiplication of cases with probabilities less than 1.0 (that is, not demonstrated), always produces probabilities of decreasing value. Although one good case can be conclusive demonstration of a proposition . . a thousand poor ones cannot" (Dincauze 1984:293).

Ultimately the very focus on the "truth" of the "existence" of the corridor itself clouds the issue. It has often been stated that one of the major unresolved problems in understanding the peopling of the New World is establishing the existence and time of the existence of the ice-free corridor. The question commonly asked can be paraphrased as, "Was there or was there not a Late Wisconsinan maximum ice-free corridor"? Phrasing questions this way is necessarily limiting and can result in simplistic interpretations. More can and needs to be considered than simply a demonstration of existence. If all one is trying to prove is existence, that is all one is going to find out.

In any scientific endeavor, one gets answers only to questions that are asked. The data do not speak for themselves. In addition, focusing on one question or event necessarily leads to reliance on the argument of elimination, in which all data not in support of the preferred conclusion are disregarded or ignored altogether. In this case, for example, focusing only on the *existence* of the ice-free corridor leads to a static, classificatory approach to the environment. As Butzer has stated, "certainly the environment is specified as a variable in most processual equations, but in all too many instances such an equation is then resolved by treating that variable as a constant" (1982:4).

Many archaeologists see the corridor as a passive entity, something that one "passes through" or "crosses," without any active interaction taking place. Jennings (1974), for example, presented a map of the ice-free corridor at 12,000 B.P. (Fig. 1.1) that he based on Prest's 1969 map of recessional ice marginal positions. Jennings showed an impossibly narrow corridor, which by lack of discussion to the contrary he implied to be a viable migration route; the environment was taken for granted. Like many archaeologists using geological data Jennings seemed to be assuming that once the geology was "defined" he could move on to the anthropological questions. Canby (1979:350) also takes the environment for granted, treating the corridor merely as a backdrop or scenery for the activities of man when he states "doubtless it was a formidable place, an ice-walled valley of frigid winds, fierce snows and clinging fogs . . . Yet grazing animals would have entered, and behind them would have come a rivulet of human hunters."

Jennings and Canby exemplify those who assume that the corridor environment was viable; with ample animals, plants, fish and fowl to support human populations; that it was easy to cross; and that passage through to the plains would take but a short time. Yet these basic assumptions remain unstated and most importantly unexamined by them or other supporters of a Late Wisconsinan ice-free corridor. In their single-minded focus on existence they are missing the point. The question is not existence. The question is environmental viability and ecological constraints. Before one can begin to examine the theoretical range of cultural activities "it is necessary first to know the range of environmental parameters that might have shaped and controlled cultural options" (Fladmark 1983:38). They do not see this point because they view the environment only as background to human cultural systems.

It has been said that archaeologists have realized that "the study of archaeological context must go hand in hand with understanding of the matrix in which remains are embedded" (Wood and Johnson 1978:315). Yet

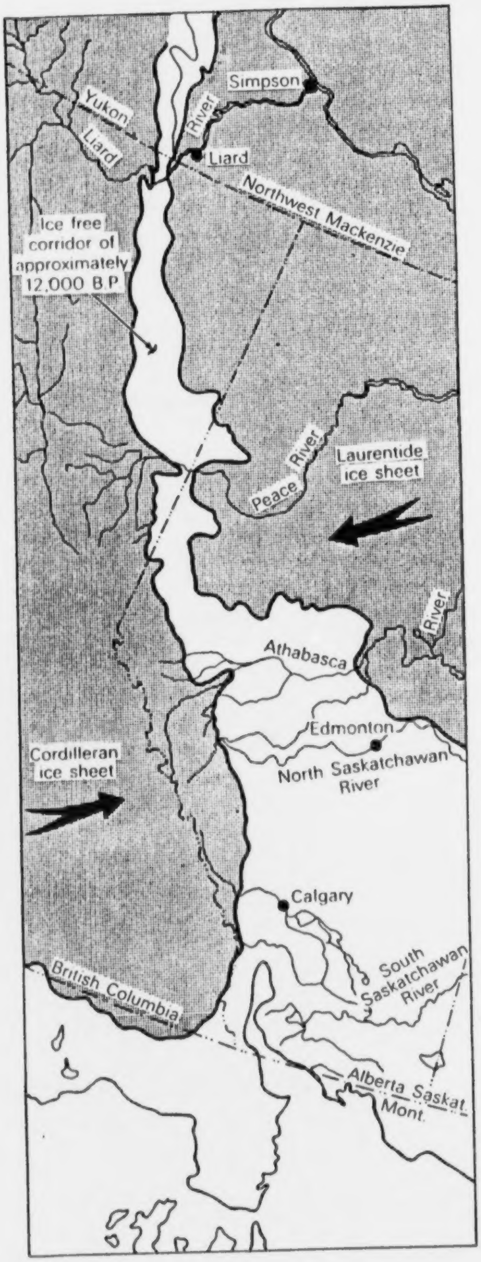

Simpson
Yukon
Liard
River
Liard
Northwest Mackenzie
Ice free corridor of approximately 12,000 B.P.
Peace River
Laurentide ice sheet
River
Athabasca
Edmonton
North Saskatchawan River
Cordilleran ice sheet
Calgary
South Saskatchawan River
British Columbia
Alberta
Saskat.
Mont.

Figure 1.1 "Ice masses at 12,000 B.P. showing ice-free corridor". From Jennings (1974:Fig. 3.23). Reproduced with permission from J.D. Jennings.

when most archaeologists hear "context" they think of an artifact in a site, or perhaps a site within a region. They rarely conceive of a dynamic relationship between the larger physical and biotic environment and cultural systems. This deficiency may explain how Meltzer and Dillehay (1991) after citing archaeologists' isolation from paleoecologists, geologists, and ecologists as one flaw in studies of the peopling of the Americas, can go on to say, "we are interested in how the first Americans made it to the New World — the *ecological stage across which they traveled*" (Meltzer and Dillehay 1991:2; emphasis added).

People do not travel across an environment; they interact with it. To answer the question of the environmental viability of the ice-free corridor, humans must be examined in the context of the environment of the corridor; not just where they were in it, or how it looked as background, but the whole weaving together of a dynamic changing environmental matrix and the human cultural systems embedded in it. Only then can we hope to determine the reality of the ice-free corridor and supplant the myth.

1.5 Methods of Analysis

The reality of the ice-free corridor can only be established on the basis of data from the corridor itself. Therefore the necessary first step in the reconstruction of the physical or abiotic environment is a survey of the currently accepted glacial stratigraphy and geochronology. In the 1930s the extent of geological knowledge warranted reference to an "ice-free corridor." Today, however, with our greatly expanded knowledge of the multifaceted nature of the Wisconsinan, its multiple advances and retreats, it is no longer tenable to speak of *an* ice-free corridor. As has been already stated, the question is not as some would have it, whether there *was* an ice-free corridor. There was, or more accurately there were several. By definition an ice-free corridor exists in the absence of ice. However, there cannot be a corridor without ice sheets to define its boundaries. Thus each glacial period will result in a corridor of some sort. Four categories of glacial activity may result in ice-free conditions thus "causing" an ice-free corridor,

a) early stages of an interglacial,
b) an interstadial,
c) pre-glacial maximum advance, and
d) deglaciation.

Each of the above would necessarily result in different environmental conditions. Therefore the question is not simply one of existence but of first precisely when and where these corridors were, and secondly and more importantly, what they were like.

Geological maps and publications were examined to establish the glacial stratigraphy and geochronology of western Canada in order to define the actual ice-free corridor area and estimate its times of existence. Locations of proglacial lakes and stagnant ice, both significant aspects of ice-free corridor environments were identified. Landforms and soils, and the processes that form and modify them were considered. In addition to data from geology, geography, and pedology, climatological literature was reviewed to evaluate the implications ice sheet placement may have had on circulation, aridity and other climatological conditions in the corridor area.

Once the physical environment has been defined attention can be given to the flora and fauna of the paleoecosystem. Pollen analysis serves as the principal technique in vegetational reconstructions of late Pleistocene conditions. The pollen grains of plants are highly resistant to decay in anaerobic conditions and as such are often found in sediments deposited in lakes and bogs. Sample sediment cores can be taken, and the pollen extracted, identified under high power microscopes, and counted. As pollen is an extremely abundant fossil it can be subjected to statistical treatments and used to reconstruct and trace vegetation history and environmental change. Therefore, reconstruction of the biotic components of the paleoecosystem begins with one of the smallest, yet most useful elements, pollen.

Four to six meter long (5 cm wide) sediment cores have been obtained as part of this research program from two lakes and one pond in the corridor area. Data from these cores are used to establish a detailed paleoecological record: a reconstruction of the vegetation based on influx data, macrofossil assemblages, comparison of modern and fossil pollen spectra, and the present ecology of individual taxa concerned. Once this record is established, and combined with the previously defined abiotic components, the productivity of the vegetation is considered. The data are then synthesized to produce a comprehensive model of the paleoecology of the ice-free corridor against which concerns of human carrying capacity are tested.

Traditionally, "attempts to determine whether or not human populations are near their environmental carrying capacity were conceptually flawed since they assumed a 1:1 relationship between food abundance and human density" (Belovsky 1988:345). Although environmental production sets upper limits to the human food base, it doesn't necessarily follow that a population will in fact reach these limits. In other words, environmental production limits, but does not determine, population levels.

The classic definition of carrying capacity referred to the maximum population size that could be supported by a given environment. The total amount of food an environment could provide was estimated and divided by per capita human requirements to arrive at a maximum sustainable population. Such methods of estimating carrying capacity that use averaging and/or short-term observations during favorable periods are actually measuring a "maximum" carrying capacity (Hassan 1981:167).

The maximum carrying capacity cannot be used as an indicator of human population levels. It is instead an abstract ideal measure akin to the Hardy-Weinberg law of genetics. Both concepts presume untenable assumptions of homogeneous, nonvariable, nonfluctuating (and in the case of carrying capacity, nonutilized), environments. Similarly, their main utility is as abstracted idealized views against which reality may be compared and differences subsequently investigated.

Instead of unrealistic maximum levels of carrying capacity, what is of interest here is what Hassan (1981) refers to as the "optimum" carrying capacity. Hassan first defines the "critical" carrying capacity as that level that considers resource fluctuations and the abundance of nutritionally critical resources. Theoretically, populations would live below the critical carrying capacity, at the optimum carrying capacity, a level that would allow a cushion against resource and/or population fluctuations (Hassan 1981:167). Whether the optimum carrying capacity is ultimately culturally (Hassan 1981) or environmentally (Belovsky 1988) driven does not affect its utility as a measure of possible hunter-gatherer densities.

Injecting human beings into the environment is clearly the most difficult task. Doing so is largely an exercise in what Soffer (1985) terms "descriptive modeling," as opposed to the more sophisticated and rigorous area of predictive modeling, which suffers from problems of justifying behavioral assumptions, methodological difficulties and problems of scale (Jochim 1983; Keene 1983; Soffer 1985). The actual evaluation of the reconstruction of the paleoecosystem draws on data from the fields of archaeology, ethnography, demography, and ecological anthropology. Analogies drawn from ethnographic data, for example, suggest the minimum technology required to survive in northern latitudes during the Pleistocene resembled the apparent technological requirements of ethnographically recent human populations in the Arctic, e.g.; tailored skin clothing, shelter, winter storage, fuel sources, and means of travel over snow and ice (Whiting et al. 1982; Diamond 1987; Powers and Hoffecker 1989). Keeping in mind the limits and drawbacks of ethnographic analogy; that ethnographic data — particularly on demographic variables — is frequently "scant, imperfect and often distorted by cultural contacts" (Hassan 1981:4), and in any case can in no way delimit past behavior, but do no more than offer an illustration of what is possible (Leach 1973:764; Soffer 1985:15), there is of necessity a reliance on the use of such analogy as a heuristic or explanatory device.

The carrying capacity of any environment is a function of harvestable primary production. Actual testing of the viability of the reconstructed model of the paleoenvironment of the ice-free corridor region will utilize ecological models that estimate probable population density of prehistoric hunter-gatherers on the basis of a consideration of available food resources in a region and the number of people who could be adequately supported by these resources. Population maintenance and growth depend on availability of food. There is a "minimum harvestable primary productivity that hunter-gatherers require to maintain a viable population" (Belovsky 1988:345).

Simulation studies of hunter-gathering populations suggest that long-term population maintenance requires a mating network of approximately 100 to 500 people (Wobst 1976; MacCluer and Dyke 1976; Fix 1981). This is considered a minimum level, as various circumstances — including linearly spaced resource availability (which we might in fact expect to find in a "corridor"), by decreasing access to certain segments of the population — would require an increase in population size. The ultimate viability of the simulation model of the ice-free corridor paleoecology is tested by introducing this minimum population into estimates of resource potentials, and the outcome evaluated. If the environment as reconstructed is calculated to be capable of supporting the hypothetical population the corridor will be demonstrated to have been a viable human environment; if, on the other hand, it is judged not capable of supporting the minimum population it would therefore be demonstrated to be nonviable as a human environment.

1.6 Implications

If it can be shown that the corridor, as an ecosystem, was or was not an effective barrier to humans, there are various possible implications. If the corridor can be demonstrated to have been a nonviable environment and thus a barrier to humans, it would help explain the relative paucity of early archaeological sites in North America south of the borders of the ice sheets. It also would imply that archaeological sites dating to the time of the corridor's existence are,

1) evidence of migrations that occurred before establishment of the barrier,

2) all more recent than their excavators would have us believe,

3) nonarchaeological, or

4) remains left by people who arrived in the New World via another route. This last possibility would call for an evaluation of the viability of the coastal route (Fladmark 1983, 1986; Gruhn 1989).

On the other hand, if the corridor was not an effective barrier, then it is no longer an archaeological issue. This conclusion would have no bearing on the legitimacy of southern sites, which would all still have to be 'proven' on individual grounds. A lack of a barrier would simply remove *apriori* reasons for not accepting early sites. Additionally, it must be stated that demonstrating that a corridor may have existed for people to pass through does in no way prove that they did. It would certainly be possible for a corridor to have existed and not have been utilized. So as far as archaeology is concerned, demonstrating the existence of a barrier would have more significant results than vice versa.

2. Historical and Political Background

2.1 Introduction

Although the compelling phrase "ice-free corridor" was coined by Ernst Antevs in 1935, the concept it stands for was initially set forth in 1933 by W.A. Johnston, a Canadian geologist, at the Fifth Pacific Science Congress on "The American Aborigines: Their Origin and Antiquity" in Victoria, British Columbia. That the subject matter of this conference concerned an interdisciplinary approach to the relationship between the Pleistocene time period and human presence in North America shows how much anthropological thought had changed since the turn of the century.

In the first quarter of this century the prevailing opinion concerning human entry into the New World was that it was quite recent, perhaps no longer than 3,000 years ago. An Asiatic origin was taken for granted, with an assumed migration via a land bridge across Bering Strait (Mason 1931:28; Wissler 1933:169; Spinden 1933:222). This intuitively "logical" idea had been proposed several times in earlier centuries, in 1590 by Joseph de Acosta (Huddleston 1967:51), in 1610 by Edward Brerewood (Randahl 1979:9), and 1794 by Ignaz Pffefferkorn (Ives 1956:421). It subsequently became an "article of faith necessitated . . . by the absence of any other plausible route" (Mason 1962:245). Once across the strait, it was generally felt that the most likely route would be down the Northwest Coast. Cultures of the past 3,000 years certainly had the required navigational and sea-going skills, and thus it was believed that the first immigrants to the New World would be coastal people. An origin from interior Asia was considered unlikely (Thorpe 1905:70).

The individual most influential in forwarding the recent arrival theory was Hrdlicka, of the Bureau of Ethnology in Washington, D.C.

Hrdlicka's zeal was in part a reaction to unfounded, unscientific claims over the previous 50 years, when the inability to interpret properly the deposits in which artifact assemblages or human remains occurred caused many problems and frequent claims of impossible antiquity (Roberts 1940:51). Hrdlicka's contention was that humans had not arrived until postglacial times (Hrdlicka 1918:37). His insistence on the morphological dating of fossils, itself an unscientific approach (Stewart 1949:2), resulted in complete denial of antiquity greater than a few thousand years. Few dared to disagree. Because of Hrdlicka's position and the power he wielded, he was able to enforce his viewpoint and effectively blocked research into the remote past. The question of early man became taboo in professional circles.

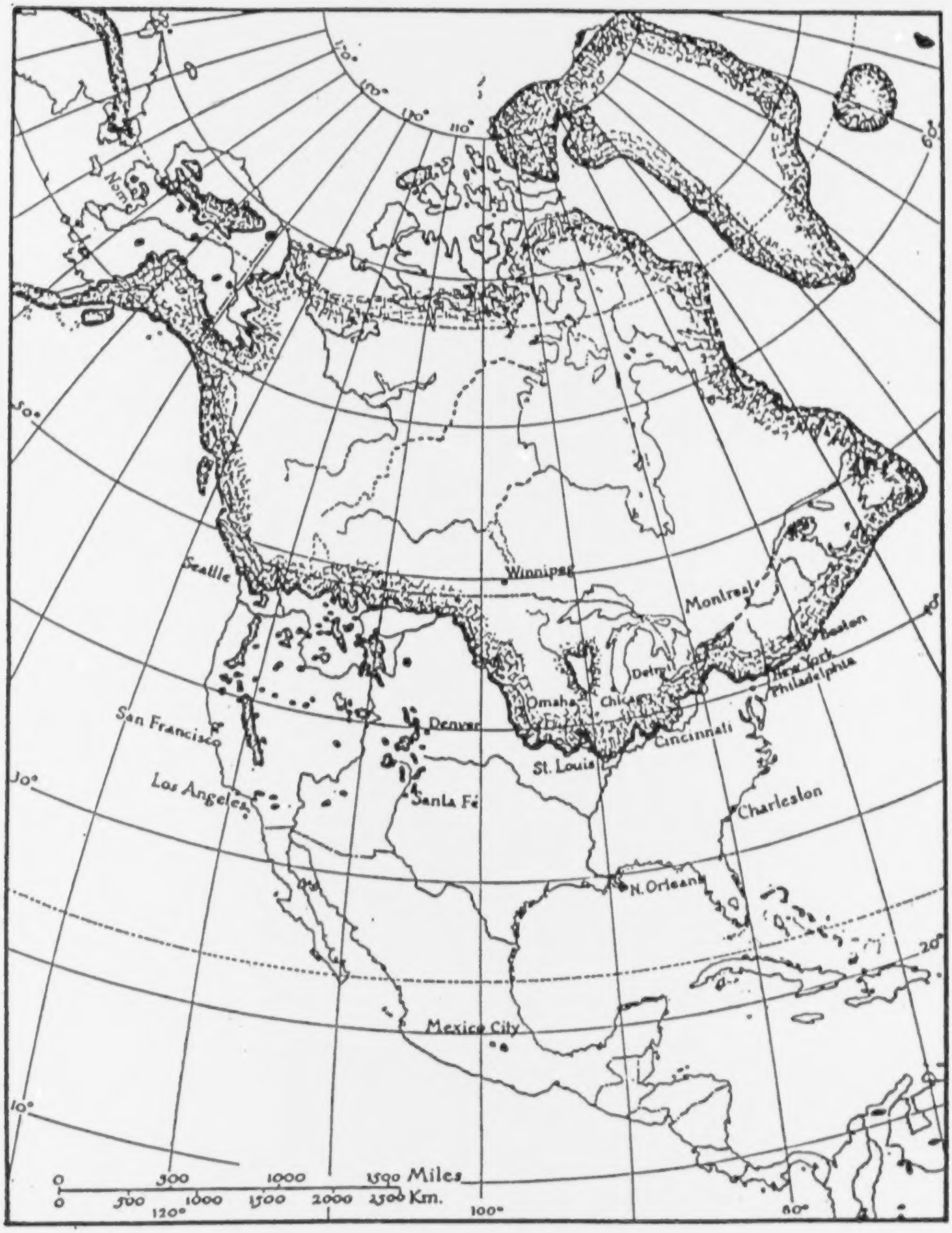
Changes began in 1927 with the clear demonstration at Folsom, New Mexico, of the contemporaneity of artifacts with the bones of extinct mammals (Figgins 1927). Most archaeologists of the time held the view that the search for early humans was a waste of time. Thus it is not really surprising that the find was made by a member of a different discipline. J.D. Figgins, a paleontologist with the Colorado Museum of Natural History, held no preconceived ideas about human antiquity (Rouse 1976:598). Acceptance of this convincing evidence of human antiquity gave a great impetus to the study of early human origins, migration routes, and culture.

The fact that Figgins' discovery linked early humans with Pleistocene mammals indicated the existence of humans during glacial times. This association fed speculation that humans and other mammals of Old World origin migrated over a land bridge in times of mild climate and ample sources of food prior to the ice sheet advance which subsequently pushed them farther to the south and eventually into South America (Goddard 1927:264).

It was soon realized that the positions and extent of the Pleistocene ice sheets were important factors in the migration and distribution of plants and animals, including humans. Consequently, Antevs was asked by the Geological Society of America to compile the scattered data on the extent of glaciations worldwide. A partial result of his effort was a map of North America (Fig. 2.1), entitled "Areas glaciated during the Pleistocene" (Antevs 1929:653). Unfortunately there was no explanatory text to accompany the map, which led many to the erroneous assumption that the map indicated a *contemporaneous* extent of glaciation instead of merely indicating areas that *at some time* in the Pleistocene had undergone glaciation.

2.2 The Early Years: Initial Proposal and Elaboration of the Ice-Free Corridor Concept

As more Folsom and Folsom-like points were found in the area east of the Rocky Mountains, it seemed logical to look north from the Great Plains to Asia for Folsom's origin. It was the Plains location of these earliest documented sites that first brought the focus to bear on the ice-free corridor area as a possible migration route, as opposed to the coastal or interior British Columbia routes. As previously mentioned, the ice-free corridor route was originally proposed by Johnston in 1933. It was later expanded upon by Antevs (1934, 1935) and Howard (1935, 1936b, 1936c). As originally conceived, the idea called for the formation of a broad ice-free belt east of the Rocky Mountains extending into the Mackenzie River valley during the final retreat of the late Wisconsinan ice (Johnston 1933:12). At that time the climax of the Late Wisconsinan glaciation was considered to


Nome
Seattle
Winnipeg
Montreal
Boston
New York
Philadelphia
Detroit
Chicago
Omaha
Denver
San Francisco
Cincinnati
St. Louis
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Santa Fé
Charleston
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170°
150°
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110°
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40°
30°
20°
10°
120°
100°
80°

Figure 2.1 "Areas glaciated during the Pleistocene" From Antevs (1929:Fig.9). Reproduced with permission from the Geological Society of America.

have been approximately 40,000 years ago, with deglaciation beginning soon after and taking 30,000 years. Antevs had arrived at this estimate by combining his work on varves in New England with estimates of the time of formation of the gorge at Niagara (Antevs 1928:168).

The route from Alaska was determined to be "uncovered by ice at an early stage . . . 30,000 - 25,000 years ago" (Johnston 1933:24). This timing was later amended by Antevs to 20,000 to 15,000 years ago, as he adjusted his Late Wisconsinan maximum to approximately 25,000 years ago (Antevs 1935:302). The region's environmental viability and inhabitability soon after deglaciation was questioned, as human existence, if even possible, was likely to have been "hard and precarious" (Antevs 1935:307). In summary, "an ice-free route . . . open from central Asia, across Bering Strait . . . to Alaska, up the Yukon valley, across into the Mackenzie watershed, and down the eastern edge of the Rockies" (de Laguna 1936:7) was believed to have been formed during the Late Wisconsinan deglaciation along the retreating borders of the ice sheets, an event then calculated to have been some 20,000 to 15,000 years ago. As this interpretation did not conflict with the estimated date of 15,000 - 12,000 years for Folsom sites in the Great Plains, it was readily accepted by archaeologists who were keenly interested in tracing the route by which the carriers of the Folsom culture had entered North America. At the time Folsom was presumed to be the oldest American culture, introduced to the New World by migrants from Asia. It was not until Sellard's 1949-1951 excavations at Blackwater Draw that Clovis was demonstrated to be stratigraphically and chronologically earlier than Folsom (Sellards 1952:149).

In 1935 extensive surveys were done by de Laguna in the Yukon Valley of Alaska, in the hope of turning up evidence of Folsom artifacts that would validate the proposed route. There was, however, no archaeological evidence discovered that would indicate that route had in fact been taken (de Laguna 1936:7). Also in 1935, Howard traveled to Russia, to study extensive museum collections of artifacts from Siberia, and search for relationships to Folsom and Folsomoid (Clovis) points (Howard 1936a:371). He too was less than successful, returning home to state, "we are, therefore, led to assume that this type of spearpoint and the technique involved in making it represent, so far as is known at present, an American development" (Howard 1936c:333).

Thus from the very beginning, the ice-free corridor route of migration of early man into North America was shown to be insufficiently supported by archaeological evidence. This fact did not, however, seem to have any impact on its appeal to archaeologists, who with some exceptions, engaged in much speculative interpretation and predictions of validating sites. While accepting the likelihood of the route, some questioned whether it could be shown that people were culturally prepared to travel it (Spinden 1933:109); or pointed out that likelihood does not equal demonstration (Smith 1937:90), a fact often ignored. But in general, by the time of the 1937 International Symposium on Early Man in Philadelphia, the concept of a late-glacial ice-free corridor through which man had migrated to central North America was a common assumption.

Also by 1937 geological knowledge had advanced to the point of recognizing multiple Pleistocene glaciations; and pre-Late Wisconsinan corridors were discussed. The corridor was considered to have been blocked by ice barriers for long periods of time, with only three instances during the last 100,000 years when humans could have entered North America. These periods were during the Sangamon interglacial, then dated to prior to

70,000 years ago; the Mid-Wisconsinan interstadial, approximately 40,000 years ago; and the aforementioned deglaciation corridor of approximately 20,000 years ago "when with the final retreat of the Wisconsinan ice sheets, the passage east of the Rockies was permanently opened" (Gladwin 1937:25). Although there was now the concept of multiple corridors it was universally assumed that migration during a pre-70,000 corridor was illogical, and one at 40,000 extremely questionable due to lack of evidence of a modern population in northeast Asia to draw upon. Therefore, the corridor at 20,000 years ago was accepted as the most likely time for migration (Antevs 1937:126). This view generally prevailed throughout the 1940s (cf. Collier 1947) as accumulating Paleoindian sites on the Plains lent support to the inland route (Roberts 1940:104). The 1940s also saw some consideration of the character and environment of a late-glacial ice-free corridor. It was recognized that the corridor could not be a viable environment until vegetation adequate to support animals had reoccupied the deglaciated surfaces (Martin, Quimby, and Collier 1947:81; Sauer 1944:336), and even then would be a harsh environment requiring specialized hunting techniques and advanced cold weather adaptations.

One dissenter from the prevailing view of a late-glacial deglaciation corridor was K. Bryan (1941:512), who incorrectly cited Antevs as stating that human entrance into the New World must be later than 15,000 years ago or else pre-Wisconsinan. This misreading of Antevs, along with a supposed 25,000 year old date for Folsom artifacts at Lindenmeier, was taken by Bryan as supporting entrance through an earlier corridor prior to the advance of the Late Wisconsinan ice. Bryan's position is interesting for a number of reasons. He was the first to question Antevs, long considered to be the ultimate authority on North American glacial chronologies.

Secondly, in order to support his position more adequately, Bryan used data selectively, foreshadowing such abuses of argument in the years to come. He misleadingly cited the *late* end of the 15,000 - 20,000 span considered as the time of opening of the corridor and the *early* end of the 12,000 - 25,000 span approximated for Folsom (which in any case applied to Lindenmeier only, and was questioned on its noncongruence with other Folsom sites). The plausibility of Bryan's position was given support by Sauer's assertion (Sauer 1944: 535) that the timing of the corridor was uncertain. It is possible that Sauer's comment was meant merely to acknowledge Bryan's opinion; certainly no geologic evidence was given to support the contention that Antevs' estimate was questionable. But in any case, by casting doubt on the traditional view Bryan and Sauer opened the way for alternatives.

Sauer's 1944 article was also the first instance of a subtle abuse of argument related to choice of words. Sauer noted that the association of Folsom artifacts with glacial and fluvial deposits raised the question of the "earliest moment at which a *gap* opened in the Wisconsinan ice of Canada through which immigrants might have *squeezed*" (1944:336, emphasis added). In the absence of hard data to support a particular viewpoint, the choice of colorful words can easily paint a picture closer to the proposed view of the speaker than would otherwise be possible. Whether intentional or not, and although he does in fact consider nutritional requirements, Sauer opened the door to conceptions of "ice-walled valleys" funnelling hunters south. Unfortunately, such concepts, once in print and available for misquoting out of context, seem to take on a life of their own.

The idea of a late-glacial deglaciation ice-free corridor, as conceived and elaborated on in the 1930s and 1940s, was immortalized in 1950 in MacGowan's widely read text, Early Man in the New World, which unfortunately was written prior to widespread ^{14}C dating and the consequent changes in chronology that ensued. In his book MacGowan discussed the alternate entry routes available and put the periods when a corridor may have been open at more than 75,000 years ago, approximately 40,000 years ago, and approximately 20,000 to 15,000 years ago (MacGowan 1950:20). He also presented the first actual outline of the Late Wisconsinan deglaciation corridor as conceived by Antevs (Fig. 2.2d); Figs. 2.2a-c depicting pre-Late Wisconsinan ice limits appeared earlier in Gladwin (1937:26-28). MacGowan considered various estimates of the timing of possible entry through a corridor and argued that 10,000 to 25,000 years ago was the most logical time period (1950:24,220). Hence this interval, and especially the possibility of entry as early as 25,000 years ago, passed into anthropological mythology, even though not long after the publication of MacGowan's book it was shown to be an untenable position. When Sellard's Early Man: A Study in Prehistory was published in 1952, ^{14}C dates, although beginning to be available, were not yet universally accepted. In addition, the few dates mentioned by Sellards were not really incorporated into the text, nor their implications fully realized.

2.3 The Middle Years: ^{14}C Dating and Theoretical Retreat

Soon, however, with refinement of the ^{14}C technique and numerous corroborative dates, it became clear that many early archaeological sites, and especially the Late Wisconsinan glacial chronology were much more recent than had been previously believed. "The new conception of a very short Recent [Postglacial] period was hard for both the geologists and the archaeologists to assimilate" (Jennings 1974:65). If Antevs' and Johnston's concepts were retained but applied with the new dates, the corridor would

Figure 2.2 has been removed because of copyright restrictions. It was a copy of K. MacGowan's (1950) map showing ice fields at different times during the Wisconsinan.

be opening approximately 8,000 to 9,000 years ago, which was much too late to have been the entry route for the makers of Clovis and Folsom points. This realization caused dissent, denial, and eventually retreat among former supporters of the corridor hypothesis, and resulted in the concept being totally ignored while the research focus shifted to the Bering land bridge.

Many archaeologists were enamored with the "new" idea (which geologists had been discussing for twenty years) of an extensive land bridge forming in the Bering Strait area as a result of lowered sea levels during glacial advances (Linne 1955:212; Sauer 1957; Chard 1958:23). This area of exposed land came to be called Beringia. Throughout the mid 1950s, when migration routes were considered, it was the routes across Beringia, the character of the environment, and the possibilities of survival in that region that were of interest. Byers (1957) imagined the region to be cold and windswept, a gently rolling landscape dotted with lakes; while Mather (1954:312) did an analysis of the interrelationship between climate and culture, focusing on the critical heat exchange of poorly clothed people to the environment; and demonstrated that "prolonged temperatures below the freezing point place severe limitations on the existence of poorly clothed man." Mather further concluded that any people migrating from Asia to North America would undoubtedly spend several generations in Arctic conditions and would likely not have been able to survive without adequate tailored clothing such as utilized by the present day Caribou Eskimo. Following this surge of research on Beringia, some writers mentioned it in their introduction to an analysis of the sites or cultures on the Plains and then offered no explanation whatsoever of how people had gotten to the Plains from Beringia (e.g. Bushnell and McBurney 1959:94).

Numerous archaeological surveys throughout the 1940s and 1950s failed to turn up conclusive evidence to support the viewpoint that the Clovis and Folsom Paleoindian cultures were imported from Asia (Johnson and Raup 1964; MacNeish 1959; Rouse 1976), but "so long as Siberia remained a *terra incognita*, it was assumed that the proofs must be there, awaiting only the spade of the excavator. The proposition was argued, as it were, on the grounds of historical necessity" (Chard 1959:44). But the facts were that "none of the Siberian Paleolithic cultures has so far shown any specific resemblances to New World ones" (Chard 1959:45), leaving Chard to conclude that any records of a migration were most likely wiped out by rising sea levels. Polyhedral cores, microblades, and burins such as found at the Campus and Iyatayet sites in Alaska, which did exhibit relationships to Old World traditions were considered to be more recent than Folsom (Rainey 1940; Giddings 1951).

Due to this conspicuous lack of evidence for the precursors of the makers of fluted points, it came to be believed during the 1950s and 1960s that fluted points were indigenous to North America and that the first Americans must therefore have arrived at an earlier time bringing an ancestral form of culture with them (Rouse 1976:598). As will be explained below, it was also realized that a corridor formed during deglaciation of the Late Wisconsinan ice, then estimated at 8,000 - 11,000 years ago, was too late to allow for migration to central North America. Consequently, the focus turned to earlier time periods in the search for when humans had entered the New World.

A Mid-Wisconsinan arrival time, originally proposed by Bryan (1941:512) — whether during the actual Mid Wisconsinan interstadial or during the advance, but prior to coalescence of, the Late Wisconsinan ice —

while theoretically possible, was generally considered unlikely for several reasons, including

a) a lack of archaeological evidence for early modern humans in northeast Asia;

b) flooding of the central Beringian land mass;

c) the probable lack of sufficient cultural development for surviving the arctic, and

d) the fact that the idea of "masses of people moving swiftly across the strait and marching briskly down the continent in search of a pleasanter climate or in pursuit of animals that were rushing south" (Wormington 1957:251) was contrary to accepted anthropological tenets.

Therefore, if Late Wisconsinan deglaciation is too late and the Middle Wisconsinan too early, a route for migrations during the Late Wisconsinan maximum or climax was needed; something that was previously dismissed out of hand. A search was on for a Late Wisconsinan maximum corridor because theoretical necessity required that there be one. This is probably the beginning of the focus on the "existence" of the ice-free corridor as an important point to prove at the expense of an understanding of what the corridor in fact was like. There had once been a suitable ice-free corridor but ^{14}C dating took it away. However it was still "needed," and this need motivated the effort to prove that there was a corridor.

Sauer, while criticizing the "doctrine of the postglacial entry of man," contributed to the effort by arguing that evidence from known moraine systems of the Late Wisconsinan Laurentide advance suggested that the ice never did coalesce (1957:30). This conclusion was by no means an entirely new concept. More than ten years earlier, Antevs (1945:9) had stated that "the [Late Wisconsinan Laurentide ice sheet's western limit] has not been traced beyond 54 1/2° N, and it is consequently not known whether or not an ice-free lane was opened down the Mackenzie Valley, but Johnston holds this probable." That no notice was made of this statement at the time can be attributed to the fact that a Late Wisconsinan maximum corridor was not necessary, a deglaciation corridor being assumed to be adequate. And in fact, as early as 1935, Howard had discussed the feasibility of the existence of a corridor during the maximum Late Wisconsinan glaciation, while also providing an excellent example of the misinterpretation and abuse of geological information which is common in ice-free corridor scenarios of later time periods. Referring to Capps' (1931) maps of glaciation in Alaska, Howard states,

> dotted lines indicate that insufficient data are on hand to establish whether the ice sheet from the Keewatin centre actually coalesced with the mountain glaciers during the last glacial stage or whether there might not have been an open corridor from central Alaska through the upper reaches of the Yukon into British Columbia and thence onto the Great Plains, such a postulated passageway, for example, as Upham shows on a map of the glaciated area of North America....(1935:127).

Starting with the reference to Capps, an examination of the original article indicates that contrary to indicating insufficient data to establish coalescence, the dotted lines in fact indicate that the location of the boundary of the ice is approximate as determined by preliminary investigation, thus implying a certain range of error in the precise location of the boundary, not questioning its actual existence.

Secondly, in the passage quoted, Howard referred to a "postulated passageway" which he claims is depicted on Upham's (1896) map of the glaciated area of North America. Examination of the map itself (Fig. 2.3),

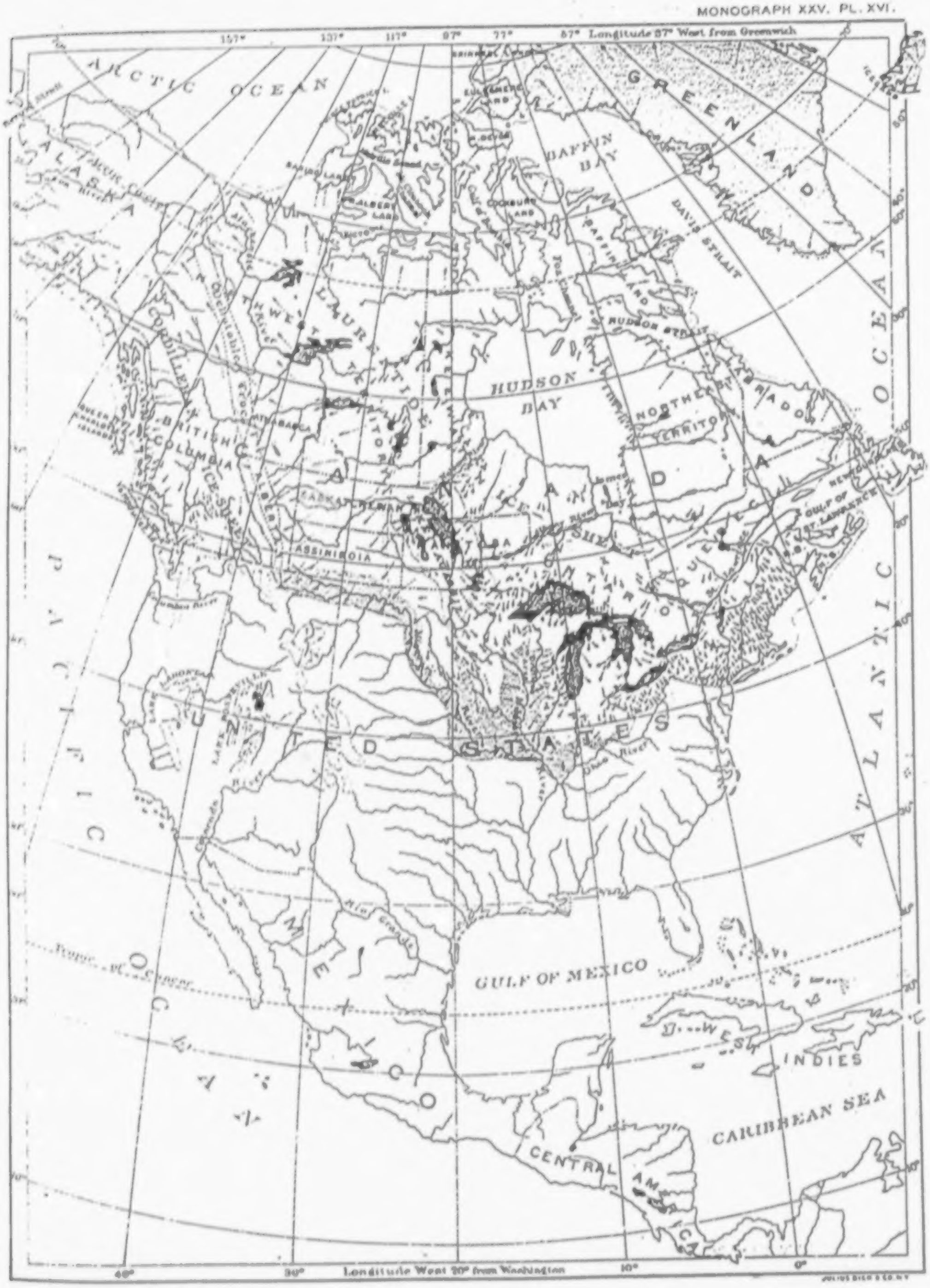
MONOGRAPH XXV. PL. XVI.
Longitude 87° West from Greenwich
ARCTIC OCEAN
ALASKA
GREENLAND
BAFFIN BAY
DAVIS STRAIT
HUDSON STRAIT
HUDSON BAY
LABRADOR
NORTHEAST TERRITORY
CORDILLERAN
BRITISH COLUMBIA
ASSINIBOIA
CANADA
LAURENTIDE
GULF OF ST. LAWRENCE
UNITED STATES
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
WEST INDIES
CARIBBEAN SEA
MEXICO
CENTRAL AMERICA
Rio Grande
Longitude West 20° from Washington

Figure 2.3 "Map of the glaciated area of North America". From Upham (1896: Plate 16). Reproduced according to the provisions of the Canadian Copyright Act.

shows a narrow area between the Laurentide and Cordilleran ice sheets delineated by dotted lines which Upham has labeled "Debatable Tract." Howard apparently jumped to the conclusion that what was under debate in this area was the presence or absence of a passageway or corridor since that is what he was concerned with in 1935. This is the earliest example I have found of a type of illogical argument caused by quoting out of the context of the state of knowledge at the time of the original statement. This has occurred repeatedly throughout the history of the development of the concept of the ice-free corridor. Additionally, Howard once more utilized a portion of a map which is not discussed in the text it accompanies, as Upham's monograph was primarily concerned with glacial lake Agassiz. This clearly added to the possibility of misinterpretations.

Unfortunately, Howard looked no further for explanations of the meaning of the term "debatable tract." What Upham in fact referred to was that the nature of the deposits, and especially the lack of any well-defined end moraine, led to much debate and difference of opinion on the mode of deposition of the glacial till in the area. The debate was not concerned with whether or not the area was ever an open passageway, an idea which was not even considered at that time.

As early as 1890 Tyrrell had noted a "narrow belt," 30 to 100 miles wide east of the mountains that he believed had not been covered by the ice sheet (Tyrrell 1890:401). Dawson also felt that the area had never been covered by "true glacial ice"; believing instead that it was submerged under a great inland sea (Dawson 1890:63). Upham, on the other hand was "equally confident that the two ice movements became confluent" (Wright 1893:97). Wright further commented that

> the opportunity for such a difference of opinion arises in the difficulty sometimes encountered of distinguishing between a direct glacial deposit and a deposit taking place in water containing boulder-laden icebergs. Where Mr. Upham supposes the ice-fields of the east and of the west to have been confluent....Dr. Dawson supposes there was an extensive subsidence of the land sufficient to admit the waters of the ocean (1893: 97).

Note that Upham in fact believed there was coalescence. His "debatable tract" was simply an acknowledgement that a difference of opinion existed. He drew his borders after Chamberlin (1894), who was depicting hypothetical and "ideal" boundaries of the extent of glacial ice (Fig. 2.4). Chamberlin also did not intend to imply a passageway, believing with others that ponded lakes would have filled the region between the ice sheets (1894:729).

An additional point ignored by Howard is that at the time Upham, Dawson, and others were writing it was believed that there had been but one ice age; the concept of more than one period of glaciation not yet having been accepted. Thus to utilize such references Howard would have had to demonstrate that the deposits referred to were applicable to the time period in question, i.e., the Late Wisconsinan. Furthermore, nearly all of the publications between the 1890s and the time Howard was writing argued for coalescence of the ice sheets in late Wisconsinan times, whether in the southern (Calhoun 1906:56; Coleman 1909:6; Alden and Stebinger 1913:547; Wright 1914:160) or northern (Johnston and Wickenden 1931:30; Antevs 1935:305) portions of what came to be considered the area of the ice-free corridor.

To return to the late 1950s, it was believed that a Late Wisconsinan migration route through the ice sheets was necessary to accommodate the known archaeological data from the Great Plains. Conveniently, the concept of the ice-free corridor as originally proposed by Johnston was

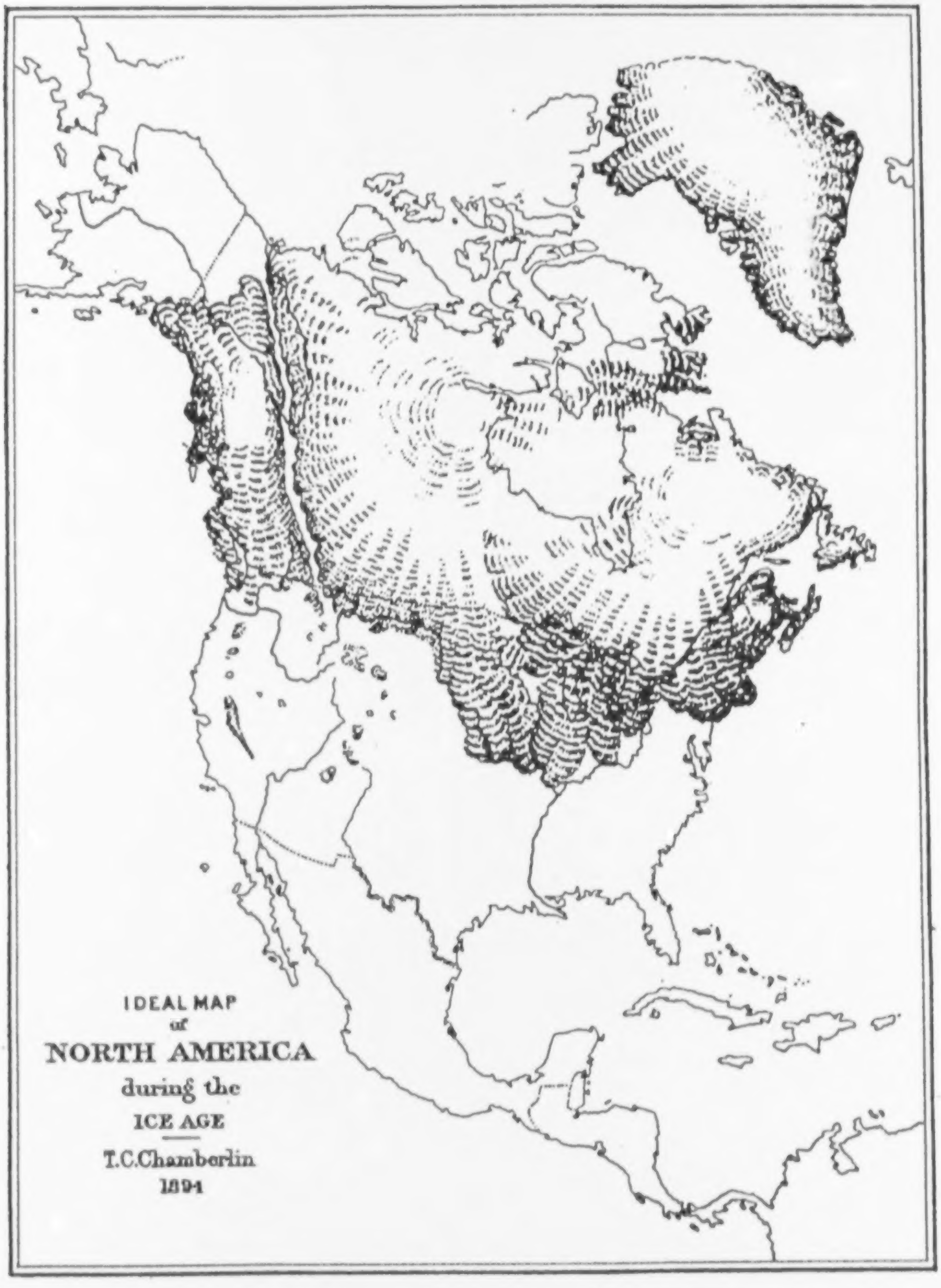
IDEAL MAP
of
NORTH AMERICA
during the
ICE AGE
T.C.Chamberlin
1894

Figure 2.4 "Ideal map of North America during the Ice Age". From Chamberlin (1894:Plate 14) . Reproduced according to the provisions of the Canadian Copyright Act.

available to be adopted by a new generation. In its new incarnation, however, only the name and general geographic location remained the same. This new Late Wisconsinan maximum ice-free corridor (as opposed to a deglaciation corridor), as defined from misunderstood ice front positions, was seen only as a passageway, a necessary route for funnelling Paleoindians south from Beringia. All pretense of environmental considerations was abandoned.

2.4 The Later Years: The Myth becomes Dogma

Throughout the 1960s, 1970s, and 1980s, and in the face of accumulating evidence to the contrary, the existence of the ice-free corridor was insisted upon. It had become a "myth," that one *believed* in, as opposed to a fact substantiated by scientific evidence. During this period there were many different approaches taken in discussions of the corridor. There was a proliferation of differences of opinion, conflicting interpretations of data, and abuses of argument. Griffin (1960) took a common approach by considering both the Middle Wisconsinan corridor and Late Wisconsinan deglaciation corridors while noting the "possibility" of a Late Wisconsinan maximum corridor. Wedel (1961:48) foreshadowed later articles, when after considering the environmental viability of Beringia, he stated that man passed southward through an "intermittently ice-free corridor" whose environmental conditions he ignored. Others claimed that there were no corridors through the ice and argued anew for the viability of the coastal route (Haag 1962:123; Mason 1962:235).

There was admittedly a great deal of confusion regarding the geological data available on the corridor area. Even when archaeologists were aware data existed to be considered — which was not always the case — they were often ill-prepared to understand or interpret it adequately. A few archaeologists accepted estimates by Bayrock (1965) that the corridor would have been closed from approximately 23,000 to 13,000 years ago and incorporated this timing into their hypotheses (Muller-Beck 1966, 1967; Clark 1969). Others ignored or denied the existence of sound geological data, leaving them to estimate timing of the ice sheets coalescence in all manner of inventive ways. Reeves (1970, 1973) for example, attempted his own synthesis of the geological data and concluded that the ice-free corridor had been in existence since Early Wisconsinan or Illinoian times. This conclusion is only possible by ignoring a great deal of available evidence including some presented within Reeves' own articles, e.g., the statement that "In the Northwest Territories, the last Wisconsinan advance of the Laurentide ice reached the mountain front, thereby sealing off any biotic movements along the Mackenzie Plains" (1973:13), which somehow escaped further consideration.

Additional creative geology is presented by Griffin (1967) and Jennings (1974). Griffin (1967:176) states that "in the absence of sound data, I assume the ice-free corridor . . . was closed only during relatively short periods of maximum ice advance and was open during most of the Wisconsinan," estimating closure at 18,000 - 16,000 years ago. Jennings (1974:100) claimed that in the face of fragmentary and obscure evidence for closure, there is agreement "that the corridor has probably always been open, although not always very wide."

Griffin and Jennings' statements are clear examples of abuse of assertion as described by Dincauze (1984:293). Assertion is the act of stating something "positively with great confidence but with no objective proof" (Guralink 1978:83). "Assertion is very useful in exposition; it avoids redundancy and moves argument along briskly" (Dincauze 1984:293). It is abused, however, when it is used in place of explanation, in order to avoid presenting one's data, assumptions, and linking arguments. In their absence, assertion is merely unsupported opinion. The fact that these opinions are held by others (cf. Irving 1971; MacNeish 1971,1973b), should not be misconstrued as constituting support, which can only come from demonstrations of scientific evidence, not personal opinion. MacNeish in fact offered a pictorial example of the abuse of assertion when he included outlines of the ice-free corridor at three periods in the last 25,000 years on maps which purportedly illustrate distributions of tool traditions (1971:78). The corridor outlines were not discussed in the accompanying text, nor mentioned in labelling the maps. By leaving the corridor undiscussed, but available as background to the artifact distributions, MacNeish asserted its existence just as surely, but more insidiously, than if he had stated so in the text.

Concomitant to arguments suffering from a lack of data of any kind is a trend to arguing the existence of the ice-free corridor, not on the basis of geological data which are presumed lacking, but on what is essentially circumstantial evidence. Wendorf (1966), for example, did a survey of dates in Canada and from these estimated the timing of ice coalescence to be from approximately 20,000 to 12,000 years ago as there were no ^{14}C dates for that period. From this conclusion he reasoned that any migrations must have occurred earlier, i.e., during the period 26,000 to 20,000 years ago. In fact, few of the dates he used are from anywhere near the corridor region. Further, the fact that his estimate approximates Bayrock's (cited earlier) is beside the point, as "one can be right for the wrong reasons. However, one cannot reasonably expect to convince others by means of fallacious arguments, nor can valid generalizations be built upon them" (Dincauze

1984:291).

While attempting to provide a broad theoretical framework for further research on early man, A. Bryan (1969b:71), presented "the working hypothesis that the 'ice-free corridor' was closed only once, between 30,000 and 8,500 years ago, (which) fits the available evidence better than the previously held assumption that the corridor was closed periodically throughout the Pleistocene until 12,000 years ago." On this basis he contended that "man must have entered Alaska prior to 35,000 years ago in order to explain his presence south of the ice sheets 11,500 years ago" (Bryan 1969a:348). Critical to Bryan's argument was his contention that there was a barrier until 8,500 or 9,000 years ago. He came to this conclusion partly on the basis of accepting Bryson and Wendland's (1967) hypothesis that cooler temperatures on the Plains after 8,500 B.P. could be explained by a corridor opening at that time, funnelling previously blocked arctic air to the south. While plausible, this is by no means the only possible explanation for decreased temperatures on the Plains. Bryan additionally argued that dates on peat bogs in central and northern Alberta ranging from 8,300 to 8,500 years ago supported his hypothesis that the corridor did not open until 8,500 or 9,000 years ago (Bryan 1969a:341). However, as MacNeish pointed out in a criticism of the 1969 article, "the dates Bryan mentions of '8,300 to 8,500 years ago' from the base of two peat bogs north of Edson, Alberta (Bryan 1968) only tell us that glacial advances were before that time, but whether the last one was five years or 50,000 years before is not demonstrated (MacNeish 1969:357). In retrospect, Bryan's data, as presented, are insufficient proof of his hypothesis. That his hypothesis was subsequently widely accepted as demonstrated, illustrates a common misunderstanding of the explanatory power of what is essentially circumstantial evidence. Data from disciplines other than the Quaternary sciences may give us useful accessory information on the nature of any existent ice-free corridor but shouldn't be considered capable of providing indubitable proof of the existence of such a corridor.

Another example of overreliance on circumstantial evidence is provided by Driver (1969). He illustrated a classic misuse of the archaeological record when, after acknowledging the presence of an ice barrier between 23,000 and 13,000 years ago, he disregarded this information and argued that the widespread localities of Paleoindian sites dated to 12,000 years ago suggest that that ice barrier "was broken by ice-free corridors, and that human groups were traversing it at this time" (1969:5). MacNeish (1976:320) went even further while discussing his proposed third stage of development of early man in America, stating,

> It might be noted that Stage III coincides with the time when ice is believed by many American archaeologists and geologists to have blocked the Mackenzie River corridor and when water flooded the Bering Strait passage. If the dates of Stage III are valid, and I believe they are, then neither of these blockages pertained, and the opinions of the many Canadian archaeologists and geologists who have studied the area and who do not believe such blockages occurred will be confirmed.

MacNeish's use of the of the words "I believe" indicates yet another instance of unsupported assertion.

The belief that archaeological sites south of the ice sheets somehow prove the existence of a corridor through the ice is a widespread misconception in the ice-free corridor literature[1]. This classic misinterpretation is a result of a form of illogic that Binford (1981) refers to as *post hoc* accommodative argument. Driver and MacNeish, like many archaeologists, describe patterning they have observed — in this case the patterning of widespread Paleoindian sites — and then interpret this patterning through *post hoc* reasoning. In doing so they have left out a crucial middle step. Scientific method consists of observation, analysis, and synthesis. What both Driver and MacNeish have done is to go directly from observation to synthesis, filling in the gap with a hypothetical explanation that the ice barrier must have been broken by ice-free corridors. Unfortunately, a hypothetical explanation, no matter how appealing or logical it may seem, cannot replace analysis. As Binford (1981:83) states,

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[1] Interestingly, the misconception continues to the present day, e.g., "[Wright 1991] recognizes that, in the end, the most effective dating of the passability of the corridor will come from the dated presence of Paleoindians south of the ice sheets" (Lynch 1991:270)

> this is where the archaeologist may build a model of the past or offer opinions as to what conditions in the past 'caused' the properties summarized. This is what I refer to as *post hoc accommodative argument* . . . this is a situation where one has isolated patterning (the effects) and seeks to use imagination to envision the conditions that, if they had happened, would account for the properties seen (the causes). The way one warrants this construction of the past may be complicated and draw on considerable knowledge, even theory from other fields. *Nevertheless, the degree of fit between the imagined conditions and the observed properties in the archaeological record is not a test of the accuracy of the argument.* Most persons are knowledgeable enough to invent a situation that, if true, would account for the observed facts . . . However, the degree of plausibility is not sufficient to establish probability.

How does one establish probability in the absence of analysis? One way is to abuse a form of argument known as argument from elimination. "Arguments from elimination have two basic premises, a) all the potential causes are known and listed, and b) all but one of those listed are not the cause of the phenomenon in question" (Binford 1981:83). Thus the remaining one is considered to be the cause of the phenomenon. When used properly this can be a powerful form of argument. Unfortunately it is often abused by archaeologists.

"A particularly interesting form of argument from elimination is one where only one possibility can be imagined" (Binford 1981:83). In this case the one possibility imagined is the existence of an ice-free corridor during the Late Wisconsinan maximum ice advance. The argument begins with the assumption that only one alternative is possible; other possible alternatives are never considered. This flawed style of argument is not restricted to interpretation of the archaeological and geological record but is in fact rampant in the ice-free corridor literature. Jennings (1974), for example, concluded that Haynes' omission of the ice-free corridor debate from the subject matter of his 1969 article "can probably be interpreted as a tacit agreement to its unimportance" (1974:100). Other explanations for omission — such as nonexistence or nonviability instead of unimportance — are ignored.

> The only positive form of argument is offered with regard to alternatives, which are rejected, so there is no direct evidence that can be offered in support of the conclusion....although these forms of argument may appear impressive and even convincing to many, unless they are actually executed with means for measuring the alternative causes or evaluating the relative contributions of differing variables said to have been active in a 'conditioning' sense, the entire exercise remains a form of polemics and is in no way an epistemological procedure. It stands as a set of ranked opinions, not a statement of probable determinacy (Binford 1981:84).

In addition, eliminating all but one possible explanation for a phenomenon runs the risk that if it is subsequently found lacking, there is nowhere to go; which may explain why supporters of a Late Wisconsinan maximum ice-free corridor become so distraught when their position is shown to be unsupported by the evidence. If, on the other hand, data relevant to several alternative explanations are collected there would be new avenues to explore when one explanation fails. Furthermore, "single solutions are rare . . . multiple working hypotheses can show how a number of factors are interrelated . . . A single hypothesis . . . more often than not produces a simplistic answer" (Dancey 1981:42).

Another concept related to reliance on the single alternative of a Late Wisconsinan maximum ice-free corridor is the belief that the timing of the corridor is fundamentally important to the dating of early archaeological sites in America (cf. Bryan 1968, 1969b:71; Shutler 1971:1). Existence of a corridor at any particular point in time does not necessarily imply anyone did in fact pass through it. Passage through the corridor, and the dating of any related sites must be established on independent grounds and cannot be inferred as implications of the corridor's existence.

A further point is the fact that Driver and MacNeish's explanations were contrary to the known geological evidence is likely related to the fact that the evidence was from a different discipline. Throughout the ice-free corridor literature, the evidence most commonly misinterpreted or ignored is that which is least familiar to the writer, making it difficult to evaluate the validity of the more detailed arguments (Lynch 1991). Haynes' (1964,1966) "Two Creeks" corridor scenario is an example of this phenomenon. In an attempt to formulate a hypothesis that would incorporate all the known data, Haynes, a geologist, proposed that the Two Creeks interstadial, dated to approximately 12,000 years ago, was of ample magnitude to create an ice-free corridor between the Late Wisconsinan Laurentide and Cordilleran ice sheets. He felt this corridor, which he estimated to have been open for only 200 years, would explain the presence of Clovis sites on the Plains 500 years later. Haynes felt Clovis points were due to a single people who had migrated down the narrow ice-free corridor in Two Creeks time, explaining the abrupt appearance of fluted points on the southern Plains (1964:1411). The first problem with his argument was reliance on untenable assumptions regarding the behavior of the supposed immigrants. In order to get them through the corridor in 200 years and across North America in another 500, Haynes postulated that the population would both increase its numbers and rate of travel at levels higher than can be supported by any known anthropological evidence. In addition, by proposing passage through the corridor within 100 years of its opening, he is by implication ignoring problems of environmental viability in the corridor. Martin's (1973) hypothesis — in which he stated that big game hunters, who "must have been delighted" (1973:970) when they first detected milder climates as their route turned southward, "threaded a narrow passage" (1973:969) between the ice sheets, exploding onto the Plains where their population multiplied astronomically — suffers from the same flaws.

The other main problem with Haynes' theory was related to the overbearing influence of glacial chronologies based on the Great Lakes area of the Midwest. Due to the nature of these glacial advances, the quantity of research done on them, and an assumption of worldwide synchroneity in climatic events, the importance of the Midwestern glacial stratigraphy was over-exaggerated for some time before it was finally realized that many of the advances and/or retreats were actually local in character (Denton 1970:34). This was in fact the case with the Two Creeks event, which was determined not to be of sufficient duration or extent to be tied to the opening of an ice-free corridor on the western Plains. In any case, recent work suggests that ice front advances dating after the glacial maximum are likely not due to climatic factors after all, but instead may be caused by ice surging of glaciers frozen to deformable beds (Teller 1987).

One of the more unfortunate trends in this period was the perpetuation of errors that had been arrived at through misunderstandings and misinterpretations of data and abuse of argument, whether the misinterpretations and perpetuations were intentional or not. Several of these misrepresentations involve maps such as MacNeish's 1971 map of the corridor which was discussed earlier as an example of abuse of assertion. Another example is provided by Spencer and Jennings (1965) who stated that there were four glacial advances in the Wisconsinan (1965:18). This statement alone is acceptable, occurring during the period of over-influence of the Midwestern stratigraphy. Accompanying the text, however, but not discussed in it, is a copy of MacGowan's 1950 map (Fig. 2.2) misleadingly labelled "Distribution of ice maxima during the Wisconsinan glaciation: a, earliest, d, latest" (Spencer and Jennings 1965:19). The implication, in the absence of explanations to the contrary, was that the four drawings were to be equated with the four glacial advances mentioned in the text, an obvious distortion of the facts. A more common misrepresentation involving maps is contradictory evidence as illustrated by Forbis (1975) who admitted coalescence of the Laurentide and Cordilleran ice sheets "dated to the maximum of the Classical Wisconsinan" (1975:18) in his text, yet presented a map depicting an ample ice-free corridor between the ice sheets labelled "Maximum glaciation in North America — the Classical Wisconsinan" (1975:19). More understandable, but by no means acceptable perpetuations of error are caused by the citing of erroneous data by later authors. Examples include Bushnell's (1968) acceptance of Wendorf's (1966) data, Anderson's (1968) use of Griffin's (1967) proposal, and Martin's (1973) use of

Haynes' (1966) arguments.

By no means were the 1960s, and 1970s entirely a wasteland of misinterpreted and misrepresented data. There was in fact a new interdisciplinary interest in environmental considerations, an increase in understanding the complexity of relationships between glaciation, climate, vegetation, and humans, beginning at the first American Quaternary Association (AMQUA) conference in 1970. Much new information pertinent to the ice-free corridor was presented. The local character of the eastern stratigraphy and particularly the over-emphasis on the Two Creeks interval was demonstrated (Denton 1970; Farrand 1970). Palynological information was shown to support a unidirectional warming trend from 14,000 to 9,000 B.P. (Cushing 1970; Davis 1970), pushing the possible opening of a deglaciation corridor slightly back in time to 13,000 years ago (Shutler 1971:1). And finally, for the first time since the late 1940s, the viability of the ice-free corridor began to be questioned. A. Stalker, a geologist with the Geological Survey of Canada, pointed out that "although a largely ice-free corridor east of the Rocky Mountains about 13,000 years ago has become a distinct possibility, its suitability for, and use by, human migrants is another matter . . . (the journey from Alaska) . . . would have been much easier, and more likely took place, when the ice-sheets were far from their maximum positions" (1970:126). Haynes, rectifying the mistakes of his earlier (1964, 1966) position, stated that in considering the corridor it is "important to realize that ice-free does not necessarily imply that it was passable to humans immediately upon ice withdrawal" (1971:8).

It was realized that consideration had to be taken of such factors as the effectiveness of stagnant ice and large meltwater lakes as barriers (Powers 1978:126). The question had become not just when had the ice retreated, but when had conditions ameliorated enough to allow passage. Stalker (1978) felt that passage may not have been feasible soon after glacial retreat, as

> Conditions would have been formidable under the best of circumstances. Fauna and flora would have had to be sufficiently established to supply the food, clothing, and firewood required for the inhospitable conditions then prevailing. Ice barriers might still have blocked sections of the route, there would have been large, frigid glacial lakes and tumultuous rivers to cross - these later swollen by drainage from the mountains, local rainfall, and the melting glaciers; there would have been chilling winds blowing from the glaciers to face, and extended periods of intense cold as man slowly worked his way 1,000 km south through the narrow part of the corridor, not knowing where he was going or what he had to face. There would have been the difficulties of crossing bogs, deltas, spurs of ice, and barren landscape left by retreating glaciers (1978:21).

Stalker's description, while admittedly speculative, considers the possible environmental restrictions which, with few exceptions, were ignored by archaeologists. Reeves does end his 1973 article with the statement that "Whether the environment was suitable for support of viable biotic populations during the glacial maxima is another matter entirely" (1973:13). Besides the fact that one cannot separate the corridor from its environment, which will be discussed later, Reeves' ploy of stating the problem so as to seem to have considered it is in no way an adequate substitute for analysis of its implications. Tolstoy (1975), for one, did realize that a narrow corridor, although technically open, "would discourage contact and tend to generate two culturally divergent areas north and south of the ice" (1975:171). His premise, however, was not widely acknowledged within anthropology.

The American Quaternary Association, maintaining its tradition of an interdisciplinary approach, devoted the entire 5th Biennial Conference held at Edmonton, Alberta in 1978 to the subject of the ice-free corridor and the peopling of the New World. Information on several aspects of the issue was presented, including new geological data relevant to the existence and chronology of an ice-free corridor (Rutter and Schweger 1980). Of particular importance were data presented which indicated coalescence of the Laurentide and Cordilleran ice sheets during the Late Wisconsinan in the area between Jasper, Alberta and the British Columbia/Yukon border (Rutter 1978; Matthews 1978). This evidence that the so called ice-free corridor had in fact been blocked for perhaps a maximum of 10,000 years during Late Wisconsinan times (Rutter 1980:7) should have demonstrated once and for all that there was not a Late Wisconsinan maximum ice-free corridor.

Like the ^{14}C dates of thirty years earlier, however, Rutter's data were not accepted with open arms but with a variety of reactions ranging from outright denial to grudgingly reluctant acceptance. A common, although certainly not new, tactic was to mention closure as a possibility to be considered, while in fact disregarding it (cf. Dumond 1980). Jennings (1983) provided an excellent example of this tactic when he concluded that "For most of the last 25,000 years, there was a corridor opened from the refuge to the northern Plains" (1983:62), after earlier in the same publication citing evidence of closure at 14,000 years ago (1983:30). He further concluded that "the corridor was a steppe where the familiar fauna grazed" (1983:62) based on faunal data from Medicine Hat, Alberta and the Old Crow, Yukon, neither of which is really in the area of the ice-free corridor, and a statement that "palynological evidence indicates that vegetation of generally steppe-tundra type grew in the ice-free passageway for at least 25,000 years"

(1983:30), although this statement is not referenced and there are no palynological publications cited in his bibliography.

In a general text on the Prehistory of the Americas, Fiedel (1987) referred to a "narrow unglaciated corridor, stretching southward from Alaska to the vicinity of Edmonton, Alberta, where it opened on to the northern Plains" (1987:46). Fiedel claimed that until recently consensus on the corridor was that it was open only during the Sangamon interglacial prior to 75,000 years ago; in the Mid-Wisconsinan interstadial of approximately 41,000 to 33,000 years ago; and again with the final Late Wisconsinan ice retreat, whereas now some geologists believed it was "open more often" (1987:47). This statement illustrates a common and unfortunate tendency for the writers of often widely read general texts to cloud the issue further by utilizing references that are several years, if not decades, out of date. The time periods Fiedel purports to have been accepted until recently come from MacGowan and Hester's 1962 text; with proposals of more frequent openings dated soon after (cf. Bayrock 1965; Spencer and Jennings 1965). Additionally, although Fiedel described the corridor as inhospitable, and very cold with meltwater lakes and swamps, he nevertheless can easily "envision one or several ancestral bands entering the northern Plains through the ice-free corridor . . ."(1987:49), thus showing no real understanding of the environmental implications.

As recently as 1991, a review article titled "Environmental conditions for Paleoindian immigration" (Wright 1991), described as "bringing to the discussion the latest evidence on the timing and extent of this between-glacial feature [the ice-free corridor]" (Meltzer and Dillehay 1991:5), in fact relies on the outdated views (Matthews 1980) and omits much recent work in the area (e.g., Kvill 1985; Catto 1986; Bobrowsky 1988, 1989; Liverman

1989a, 1989b; Catto and Mandryk 1990; Duk-Rodkin 1989; Rains et al. 1990; Young et al. 1990).

In recent years, however, there has been a realization by a few anthropologists, if not of the real possibility of the blockage of the corridor in Late Wisconsinan times, then of the beginnings of a recognition of the inhospitable environment the corridor would have had when it did in fact exist (Morlan 1987), and that ecological factors must be considered (Slater 1985). Fladmark (1983, 1986), in particular, presents an excellent and thorough consideration of whether, and in what ways environmental factors "might have limited, prohibited, or shaped human dispersals or adaptations in North America" (1983:13).

There is also beginning to be a recognition that current estimates for deglaciation eliminate the supposed conflict in timing between the opening of a deglaciation corridor and the appearance of Clovis Paleoindian sites on the Plains. There is a growing consensus among workers in the ice-free corridor region, especially for example, researchers of the Archaeological Survey of Alberta's "First Albertans" Project, that the "ice-free corridor," if defined as a Late Wisconsinan maximum corridor as per the revisionist interpretations of the 1960s, is in fact a nonentity (Ives, Beaudoin, and Magne 1989). We are now returning to the views of the 1930's and 1940's when the corridor under discussion was a *deglaciation* corridor, as a Late Wisconsinan maximum corridor once again is simply not necessary. Many researchers are convinced that the concept and in particular the term, "ice-free corridor," to have been counterproductive due to the many differences of opinion and interpretation of what it actually means. To defuse some of the charged meaning behind the phrase "ice-free corridor," A. Beaudoin, Archaeological Survey of Alberta, has recently proposed "Western

Corridor" as a replacement (Beaudoin 1989). She defines the corridor area not on the basis of ice front positions, thus avoiding that dispute, but on general geographic terms as consisting of the area bounded by the Alberta-British Columbia border on the west, and an arbitrary line joining the Albertan towns of Foremost and Fairview on the east (Fig. 2.5).

2.5 Socio-Politics of the Ice-Free Corridor

Consideration of the history of the concept of the ice-free corridor has revealed that it can be an emotional issue, often characterized by unsubstantiated speculation, faulty logic, and intense belief in the face of contradictory evidence. A look into the socio-politics of archaeological research in North America may help explain such behavior by exposing some of the means by which the political and social present affects the archaeological past. In recent years there have been attacks on the "myth of objective research" in archaeology and a call for self-reflective criticism (Gero 1985:342). The contention is that our ideas, assumptions, and interpretations regarding the past are not value neutral, but that instead, "an archaeologist's socio-political identity and context has a determining influence on his or her archaeological analysis" (Wenke 1989:33). Our values, both personal and archaeological, are embedded in and necessarily reflect the larger society of which we are a part.

Proponents of Critical Theory ask, Who owns the past? For what purposes is the past interpreted and created? (D.H.Thomas 1989). Some maintain that the state owns the past and interprets it to support and justify its own existence. It is argued that "it is only the state that can support, and that requires, the services of elite specialists to produce and control the past" (Gero 1985:342). In particular, the state requires that archaeological explanation and interpretation make the past appear like the present.

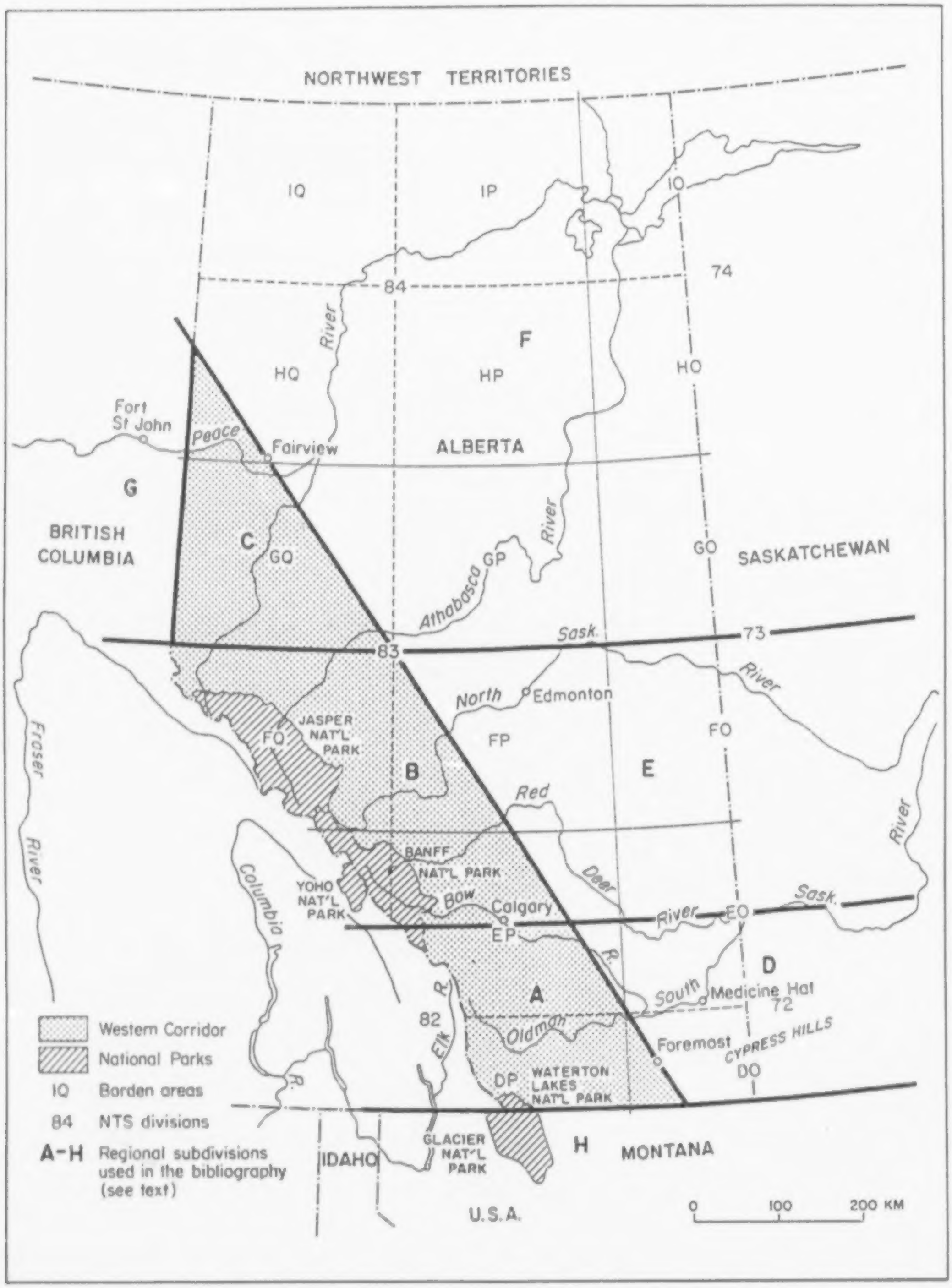

NORTHWEST TERRITORIES
IQ
IP
IO
84
74
F
River
HQ
HP
HO
Fort St John
Peace
Fairview
ALBERTA
G
BRITISH COLUMBIA
C
GQ
River
Athabasca
GP
GO
SASKATCHEWAN
Sask.
73
83
River
North
Edmonton
Fraser
River
JASPER NAT'L PARK
FQ
FP
B
E
FO
River
Red
Deer
BANFF NAT'L PARK
YOHO NAT'L PARK
Columbia
Bow
Calgary
River
EO
Sask.
EP
R.
D
South
Medicine Hat
72
A
Oldman
82
Elk
R.
Foremost
CYPRESS HILLS
DO
DP
WATERTON LAKES NAT'L PARK
R.
GLACIER NAT'L PARK
IDAHO
H
MONTANA
U.S.A.
0
100
200 KM
Western Corridor
National Parks
IQ Borden areas
84 NTS divisions
A-H Regional subdivisions used in the bibliography (see text)

Figure 2.5 "The Western Corridor". From Beaudoin (1989:Fig. 2). Reproduced with permission of the Archaeological Survey, Provincial Museum of Alberta.

Archaeology in the service of the state "consistently misrepresents the past by making it seem a logical precedent for the present; indeed, archaeology suggests the present is an ineluctable and therefore legitimate outcome of the past (Leone 1984)" (Gero 1985:343). Thus the past as constructed per the ideology of the present day social order justifies the present as its inevitable and logical outcome.

Trigger (1986:188) argues that since "what people believe about the present conditions their understanding of the past . . . It is therefore unlikely that American archaeology has been uninfluenced by the ideology of American society and more particularly by the values of the more conservative elements of the middle class to whom such studies have particularly appealed." Gero and Root (1990) do an insightful analysis of the political function of the past in the United States as exemplified by one very popular example of American mass media, the *National Geographic* magazine. They demonstrate how American ideological themes of expansionism and capitalism are effectively communicated throughout the magazine. Their analysis of 85 years of archaeological articles appearing in *National Geographic* revealed three principal ways that archaeology is used to encourage American nationalism.

First, there is the focus on the "thrill" of archaeology, done as exploration and discovery of exotic treasures by bold and competitive individuals.

> *National Geographic*'s coverage of archaeology never dwells on explanations of prehistory or technical aspects of excavation. Rather, the editorial emphasis is on the *quest:* the quest in which one must be first, and for which one must traverse great distances in order to acquire artifacts, and above all, the *unique artifact*. The most frequent photographic image in its articles on archaeology displays the *unique artifact*, torn form its original production and use context and cleared from its

> recent archaeological matrix (Gero and Root 1990:28).

Fragmentary artifacts are seldom depicted; the focus is on the finest, the biggest, the best, the first.

Second there is a tendency to humanize and homogenize the past into the American mold.

> Frequently the past is made more accessible through the lens of contemporary American concepts, categories and social relations, homogenizing all pasts to look like ours, and marking all prehistoric events along a timeline of the rise of Western civilization....Again and again, present-day American values are extended into the past, onto the peoples of the past, appropriated by us to represent us in an earlier state (Gero and Root 1990:29).

Democratic state systems, and in particular the United States, are portrayed as the inevitable and normal outcome of the development of Western civilization.

Third, there are systematic geographical, topical, and chronological biases in archaeological reporting, with the most attention devoted to the cultural development of Western civilization and the origins of the Judaeo-Christian tradition. Such a focus

> make[s] the past appear to be like the present and lead[s] the public to believe that the state has always existed and is the norm as well as the most successful form of social organization. This misrepresentation of the past conveniently gives a time-depth to the American state underwriting a logic that portrays this system of governance as *innately* human and intrinsic to the human condition (Gero and Root 1990:33).

It is pertinent to this discussion to take Gero and Root's analysis a bit further to include a *National Geographic* issue published after their paper was written. The October 1988 issue of *National Geographic*, titled "The Peopling of the Earth," illustrates many of the ideological influences summarized above. With this issue we can move past a general consideration of the influence of American ideology on archaeology to analyze the American mythos regarding the particular issue of the peopling of the world, and hopefully gain insights in attitudes towards an ice-free corridor's role in the peopling of America.

The *Peopling of the Earth* issue amply illustrates support for American nationalism, and the United States as an inevitable outcome of Western civilization. Though titled "Peopling of the Earth," the recurrent subject matter of the issue is clearly on the peopling of North America, and the origins of Americans.

In an introduction to the issue entitled, "Where did we come from?", ostensibly referring to the origin of modern humans, the focus is on a kind of directed migration to the Americas. "Whether driven by fear, hunger, curiosity, sense of destiny, or a mix of all, mankind — then as now — has continually migrated, as if to fill every void on this planet . . . man drifted north out of Africa to Europe and eastward to Asia. Millennia later, with the appearance of modern *Homo sapiens*, the great migration pushed on to Australia and the Americas" (Garrett 1988:435). Note the choice of words; e.g., "sense of destiny" is hardly a value-free phrase but is clearly suggestive of an expansionist, imperialistic view of the world. Also note that humans passively "drifted" to Europe and Asia but actively "pushed on" to Australia and the Americas.

As a perfect example of the quest for unique artifacts, the introduction next discusses the article "Weapons Cache of Ancient Americans," describing the cache as "the most magnificent collection of their spearpoints ever found" (Garrett 1988:435). And who are "they"?; the first Americans, of course. The article itself, predictably, is accompanied by a full page photo of the two largest Clovis points ever found, photographed not *in situ*, but held aloft in human hands.

Later in the introduction the migration story is extended through time from the Upper Paleolithic to the age of European discovery and colonization that began in the 15th century, to the present day where "never before in history have as many humans been on the move as in this century. It is estimated that more immigrants — legal and illegal — will have entered the United States in the 1980's than in any other decade in our history" (Garrett 1988:437). An article on the Hmong in America illustrates these most recent immigrants to America, thus completing the circle of past as present, present as past. The present day American concept of America as the promised land, goal of the world's immigrants, is pushed into the past. Confusing present with past, making it seem the logical precedent for the present, and the present as the inevitable outcome of the past, leads to blurring of identities to the extent that modern man = first Americans = *Americans*; exemplifying a popular American tendency to define others in terms of themselves, if indeed they are considered at all.

This is clearly seen in the lead article of the issue, "The Search for Modern Humans." This search is continually described as a *journey* in which the 'trail' of modern humans is followed worldwide. A search is an act of inquiry or examination that attempts to establish facts, gain knowledge; it does not imply physical movement as does the word journey, i.e., the act of traveling from one place to another (Guralink 1978:762,1284).

The journey starts in France, then moves from Europe to Africa, Asia, Australia, and finally the Americas. There is frequent focus on the Americas as the "goal," e.g., "the trail of man's journey from Asia to the Americas," or "man's route to the Americas," etc. (Putman 1988:464). The author writes, "[as] the plane lifted from Little Diomede and my journey approached its end [in the U.S], I thought of the beginning, that dark cave in France, and of all I had seen since, and of how often I had seemed almost within touching distance of our prehistoric ancestors" (Putman 1988:475). Though a non-archaeologist writing for the general public, Putman shares certain philosophical, cultural, and theoretical presuppositions with those archaeologists (cf. Fagan 1987) who "have been propelled by an Eurocentric mandate to link us to Upper Paleolithic 'ancestors'. That is, we seek to find ourselves in this archaeological record" (Conkey 1987:63).

Putman travels from France across the world on a search = journey for "modern humans." The end point of his journey is the United States of America, thus validating America as the logical outcome — if not the only outcome, clearly the best outcome — of the development of modern humans. All roads, migration routes, etc. lead inevitably to us now in the present. The Hmong came to America just as the "first" Americans did over 12,000 years ago.

To some American archaeologists the first Americans are not simply ancient inhabitants of the America continents; they are Americans barely different from themselves. The fact that the earliest Americans are actually of Asian stock whereas the majority of Americans are not is irrelevant. We are tracing a cultural past of our present selves, not a real past.

The three ways Gero and Root list that archaeology is used in the service of nationalist ideology are clearly evident in beliefs concerning the first peopling of the New World. The focus is on the quest, the exploration and discovery of exotic lands by bold and competitive individuals with the requirement of being first. The idea discussed above of America as the ultimate goal of immigrants whether today or 12,000 years ago illustrates how present-day American attitudes are extended into the past and assumed to have been held by people of the past, who regardless of actual cultural or genetic heritage are "appropriated by us to represent us in an earlier state" (Gero and Root 1990:29). This misrepresentation of the past gives a time-depth to the American system that once again makes the past appear to be like the present. America has always existed; it is the norm for humanity and the most successful form of social organization. That is the party line that state archaeologists must strive to support and defend.

Coming from this point of view, of what importance is the concept of the ice-free corridor? It is the instrument, the route, for a critical part of the story. The bold, adventurous, curious first Americans migrated to their destiny down the ice-free corridor.

The concept of the ice-free corridor is held onto so tenaciously in the face of conflicting evidence because it is a symbol of all Americans hold important. It is the first way, the best way, the difficult way, the romantic way. This conception may also help explain what motivated archaeologists to expect the earliest inhabitants to move so quickly. This was not a random drifting migration; this was directed migration — these were the first American immigrants — on their way to America, symbolized by mom, apple pie, and industrial capitalism.

That a bias appears to be present in interpretations of the American past does not imply the bias was intentional or even something American archaeologists were consciously aware of. A provocative article by Niederland (1989) suggests that many typically American phenomena and attitudes may be rooted in "the unconscious 'island' imagery of the population groups that settled in the New World" (Niederland 1989:92); that is, unfocused attributes of utopia, happiness, bliss, paradise and abundance associated with various forms of island myths (begining with Plato's invention of Atlantis) "readily attached themselves to the newly discovered land in the west [America] which on the first map naming it, appears as an island-shaped area in the region where the islands of fortune were though to exist" (Neiderland 1989:91).

It is not at all easy to recognize the messages our interpretations and reconstructions are sending. Socio-political assumptions and attitudes are deeply embedded in one's culture. It is hard indeed to unchain oneself from the cave, stop studying the shadows, and turn and face the light of reality. This is precisely why we need self-reflexive criticism to help us make our assumptions and attitudes explicit.

3. Methods

3.1 Site Selection

The ultimate goal of a research problem dictates the choice of study area and sampling strategy. As a first step toward a vegetational reconstruction of late Pleistocene conditions in the ice-free corridor, a section of the corridor area was surveyed in a search for potential coring sites that would encompass the critical late glacial period. All topographic maps at 1:100,000 and 1:50,000 scales within NTS map areas 83B, C, F, and G were scrutinized along with surficial geology maps (at 1:250,000 scale), and various air photos for the most appropriate lake basins within the presumed corridor area. Nearly 150 lakes and ponds were considered.

Given the large amount of time required for the collection and analysis of paleoenvironmental data, it is important to choose sites carefully. Several characteristics of potential sites were evaluated in the search for the most suitable deposits. These characteristics included:

a) Location in the corridor. (Fig. 3.1) as defined by Rutter (1984).

b) Geological significance. For example, a site located within the boundaries of the Athabasca or "mixed" till in the region between Rocky Mountain House and Hinton — besides providing paleoecological information — could help resolve chronological questions of the till itself.

c) Size. The surface area of a lake is one of the most important attributes to be considered as there is a clear relationship between basin size and the source area of the deposited pollen (Jacobson and Bradshaw 1981; Prentice 1985). The smaller the basin the more local the pollen representation. Berglund (1986) suggested that in forested areas, lakes of about 25 to 50 ha with a diameter of 600 to 800 m were preferred for regional

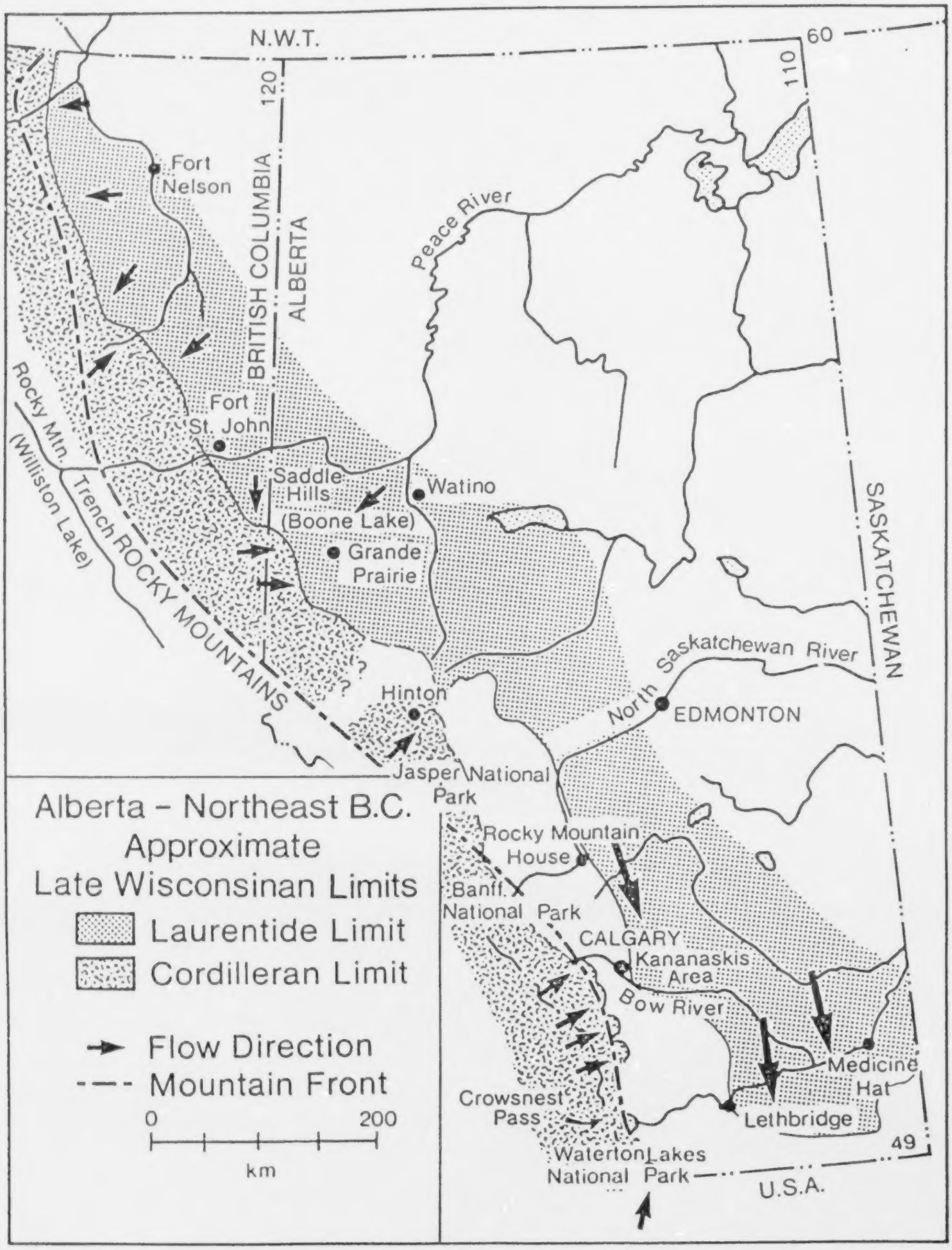

N.W.T.
60
110
120
Fort Nelson
BRITISH COLUMBIA
ALBERTA
Peace River
Fort St. John
Saddle Hills (Boone Lake)
Watino
Grande Prairie
Rocky Mtn. Trench (Williston Lake)
ROCKY MOUNTAINS
SASKATCHEWAN
North Saskatchewan River
EDMONTON
Hinton
Jasper National Park
Rocky Mountain House
Banff National Park
CALGARY
Kananaskis Area
Bow River
Medicine Hat
Lethbridge
Crowsnest Pass
Waterton Lakes National Park
49
U.S.A.
Alberta - Northeast B.C.
Approximate
Late Wisconsinan Limits
Laurentide Limit
Cordilleran Limit
Flow Direction
Mountain Front
0
200
km

Figure 3.1 "Possible Late Wisconsinan limits, Alberta and northeastern British Columbia". From Rutter (1984:Fig. 2). Reproduced with permission from the Geological Survey of Canada.

and climatic reconstructions. In non-forested areas, the optimum basin size would be 1 to 10 ha with a diameter of 100 to 300 m.

d) The presence or absence of inflowing streams. Inflowing streams bring in pollen from a much larger source area, in effect enlarging the effective surface area of the lake. Choosing a site without inflowing streams minimizes the potential of contaminating redeposited sediment. In addition, pollen-influx measurements from enclosed basins are more closely related to vegetation than is pollen influx from lakes with major inflowing streams (Davis, Moeller, and Ford 1984).

e) Depth. Deep lakes were preferred to decrease the chances of disturbance by periods of low water level and subsequent evaporation and degradation of the sediments. A deep lake does not guarantee an old lake with a record that spans the critical late glacial period but it does increase the probability that if such a record was deposited, it was also preserved.

f) Basin morphology. The morphology of the lake basin is another important characteristic to be considered in evaluating pollen data (Jacobson and Bradshaw 1981). The lake basin should be as regular and isodiametric as possible, with sides neither overly steep nor too shallow, to limit problems caused by the redeposition and focusing of sediment (Pennington 1979; Berglund 1979). Lake sites that have been hydrographically surveyed and have maps available were preferred. Several hundred lakes and reservoirs in Alberta have been surveyed and mapped by various provincial agencies (Alberta Environment 1987). In addition to revealing the regular or irregular nature of the basin morphology, such maps make available data on lake depth. Knowledge of lake depth is important both to the choice of the lake itself (discussed in e above), and to the subsequent selection of coring locations within the basin.

The deepest spot was preferred as this is where the most complete sections are more likely to be found (Birks and Birks 1980:38; Davis et al. 1984:288).

g) Accessibility. The size, weight, and bulkiness of the coring equipment (and the lack of abundant funds for helicopter rental) made it necessary to choose sites located close to a road.

To summarize, a deep lake, of 600 to 800 m or less in diameter, with no inflowing streams, which has been hydrographically surveyed (with a map available at Maps Alberta), and located in the vicinity of a road, was considered an ideal coring site in the corridor area.

The criteria as described are somewhat subjective and the chosen sites did not necessarily fulfill all criteria equally well. In addition certain sites chosen in preliminary survey could not be located on the ground because of inconsistencies and inaccuracies between topographic maps and air photos and the actual landscape likely caused by differing times of data collection. The actual sites cored were Mitchell and Strubel Lakes, both near Rocky Mountain House, Alberta, and Nordegg Pond (informal name), located near Nordegg, Alberta.

3.2 Field Methods

3.2.a Coring

All three sites were cored through winter ice at or near the point of greatest depth using a 5 cm diameter, 1 m long modified Livingston piston sampler (Wright 1967). Strubel Lake and Nordegg Pond were cored in March 1985, while Mitchell Lake was cored in March 1986.

Two or three nearly continuous series of cores were taken approximately 3 m apart at each site. Water surface to sediment depths were: Mitchell Lake, 4.45 m; Strubel Lake, 12.70 m; and Nordegg Pond, 0.90 m. A coring tower with cable and winches was required to drive the corer through volcanic ash layers and the lower silty and sandy sediments at Mitchell and Strubel Lakes, which were very difficult to penetrate with a hand operated sampler.

Core segments were extruded in the field to allow a preliminary examination of stratigraphy and detection of any obvious contamination. Each segment was measured and then wrapped, first in light plastic and then in rolled corrugated cardboard, to minimize exposure to light and air. The segments were then transported to the laboratory where they were stored in a cold room at 4 to 8 C^o until they were subsampled.

3.2.b Site Surveys

All three sites were visited in August, 1986. Local vegetation near each site was sampled and identified. In addition, field observations were made on the surrounding topography, including characteristics of soils, slopes, and drainage patterns. Particular attention was given to determining the degree of correspondence between the surficial deposits as mapped (Boydell 1978) and the deposits actually observed and sampled.

3.3 Laboratory Methods

3.3.a Sampling Procedure

The most complete core recovered from each lake was used for sediment description, pollen analysis and determinations of organic matter, water and carbonate contents. Supplemental cores were used for macrofossil analysis and radiocarbon dating after lithological correlation with the first core.

Before subsamples were taken each core segment was remeasured and described according to the composition, texture and color (Munsell 1975) of the sediments represented. Because of variations in core recovery, which is not always 100% for piston samplers (Richards 1961), and either extension of looser sediments or shrinkage from partial desiccation before sampling, the segments of core analyzed were not always a full meter in length.

Sediment samples of 1 cm^3 were taken for pollen analysis at 20 cm intervals above the Mazama tephra and 5 cm intervals below. Samples were removed from the core with a modified open-ended plastic hypodermic syringe and a metal spatula. The pollen samples were extruded from the hypodermic into small glass vials and then frozen until processed.

Sediment samples for loss on ignition determinations were taken at 10 cm intervals along the core, wrapped in small packets of aluminum foil and frozen if not analyzed immediately. Additional sediment samples were taken from characteristic stratigraphic zones along the core to allow for microscopic examination of the sediment in simple water-mount slides. These samples were stored in small glass vials at room temperature until analyzed.

Sections 5 cm long were removed from supplemental cores for macrofossil analysis. These core segments were kept in sealed plastic bags in a cold room until analyzed. After analysis of organic matter and carbonate contents, considered in conjunction with the observed core stratigraphy, additional core segments were taken from both primary and supplemental cores for radiocarbon dating.

3.3.b Pollen Processing

Only samples from below the Mazama tephra were processed. The remainder of the samples were stored in the freezer of the Paleoenvironmental Studies Laboratory, Department of Anthropology, University of Alberta. After the addition of one or two calibrated tablets of either *Lycopodium* (batch #414831) or *Eucalyptus* (batch #106720) to estimate pollen concentrations (Stockmaar 1972) and influx (Maher 1972), the sediment samples were processed by the procedure summarized below (modified after Faegri and Iverson 1975; Birks 1976; Schweger 1976; Birks and Birks 1980).

1) Sieving through a screen with mesh of 15 microns to remove coarse inorganics and organic detritus.

2) Treatment with cold HCl to remove carbonates.

3) Concentration with heavy liquids ($ZnBr_2$), followed by filtration with glass filter paper. Pollen trapped in the filter is recovered by dissolving the glass filter paper in HF. (NOTE: This is an optional step for clay-rich samples.)

4) Treatment with cold HF overnight and/or hot HF for 1 hour to remove silicates.

5) Treatment with hot HCl for 5 to 20 minutes to remove colloidal silicates and silicoflurides.

6) Treatment with hot 10% NaOH for 5 minutes to remove soluble humic acids (NOTE: This is an optional step for samples that are very rich in humates.)

7) Acetolysis for 3 to 5 minutes in a mixture of acetic anhydride (9 parts) and concentrated H_2SO_4 (1 part) to hydrolyse cellulose.

8) Neutralization with glacial acetic acid and distilled H_2O.

9) Dehydration in 98% ethanol and tertiary butyl alcohol.

10) Mounting in silicone oil (2000 Centistokes).

3.3.c Pollen Identifications

Pollen content was determined using a Leitz SM-Lux microscope. Most counts were made at 400 X (numerical aperture 0.65), although 250 X (numerical aperture 0.55) was used to scan pollen poor basal samples, and

630 X (numerical aperture 0.90) and 1000 X (numerical aperture 1.30) oil immersion were used for critical determinations. Where possible a minimum of 400 pollen grains was identified per sample. In basal sediments with low pollen concentration the minimum counted was 200 grains or 5 slides. Whole slides were counted in these pollen-poor samples. In slides with abundant pollen, traverses were split equally between the edge and center of the slide to avoid errors associated with the nonrandom distribution of pollen grains of different diameters.

Pollen determinations were made to the lowest possible taxonomic level and indicated following the conventions of Birks (1973). Identifications were verified using the approximately 3400 reference slides in the collection of the Paleoenvironmental Studies Laboratory of the Anthropology Department, University of Alberta, and various atlases and keys (Habgood 1985; Moore and Webb 1978; Bassett, Crompton, and Parmelee 1978; Kapp 1969). Grains that could not be identified were recorded as unknown; while grains that were obscured, broken, or deteriorated beyond recognition were recorded as indeterminate.

Betula pollen grain diameters were measured for 25 grains in each of five samples from each lake. Samples were spread throughout the two *Betula* pollen spectra peaks to allow comparisons of general trends in grain size measurements, although the utility of such measurements is questioned by Ives (1977) and Edwards (1988).

Although angular black fragments presumed to be charcoal and/or coal, and opaque black spherules presumed to be pyrite were ubiquitous in several samples, counting them was determined not to be practicable nor useful due to the great variance in their dimensions (ca. 3 to 25 microns). Observations were noted, however, on their presence, abundance, and general size in particular samples.

3.3.d Pollen Analytical Procedures

Only samples below the Mazama tephra were analyzed. Prior to establishment of core chronologies via radiocarbon dating, the Mazama tephra served as the only reliable means of limiting analysis to the approximate time period of interest; that is, vegetation post 6800 yr B.P. is irrelevant for the purposes of this study.

All tree, shrub, and terrestrial herbaceous taxa were included in the pollen sum. Aquatic taxa (including Cyperaceae at Strubel Lake only), spores, indeterminate and unknown grains were excluded from the pollen sum. Pollen percent, concentration, and influx values were calculated using the Pollen Data Log and Analysis Program VI (Gibson 1985).

Numerical zonation of the pollen percent diagrams was aided by SPLITINF, SPLITLSQ, and CONSLINK (Gordon and Birks 1972) computer programs modified by L.J. Maher, University of Wisconsin, Madison. Only those taxa reaching 5% in at least one sample were included in the numerical zonation. SPLITINF and SPLITLSQ results were plotted to the point where an additional division reduced the residual variation by 3% or less, as further splitting of the diagram would yield little additional understanding. The results of all four (two variations of CONSLINK) programs were used to guide the final zonation of the diagrams. Zone boundaries were drawn where two or more programs indicated a similar division. In all cases these divisions corroborated the locations of zone boundaries arrived at earlier by visual inspection of the diagrams.

3.3.e Other Samples

Determinations of organic matter, water content, and carbonates were done by the following procedure (modified after Wetzel 1970; Dean

1974).

One cubic centimeter sediment samples were placed in preweighed #03 porcelain crucibles, reweighed, and then dried in an oven at 105^{0} C for 24 hours. After cooling to room temperature in a desiccator, the samples and crucibles were weighed again. They were then placed in a Fisher Isotemp muffle furnace that was heated to 550^{0} C for one hour. After cooling to room temperature and reweighing, the samples were returned to the muffle furnace and heated to 950^{0} C for 3 hours, after which they were cooled, then reweighed a final time.

Calculations were done as follows:

Where, a = mass of crucible,

b = mass of crucible plus 1 cm^3 wet sediment,

c = mass of crucible plus sediment after 24 hours at 105^{0} C,

d = mass of crucible plus sediment after ignition for 1 hour at 550^{0} C,

e = mass of crucible plus sediment after ignition for three hours at 950^{0} C,

Wet mass of sediment = b - a

Dry mass of sediment = c - a

$$\text{Percent water} = \frac{(b - a) - (c - a)}{b - a} \times 100$$

$$\text{Percent Organic Matter} = \frac{c - d}{c - a} \times 100$$

$$\text{Percent Carbonates} = \frac{d - e}{c - a} \times 100$$

Macrofossil analysis was done primarily to obtain specimens for dating purposes. Selected sediment samples were first soaked, then wet sieved through 40 and 100 mesh screens using distilled water. Macrofossils were picked from the residues on the screen with fine tweezers and a wet #0000 paintbrush and stored temporarily in distilled water.

Macrofossils were airdried just prior to examination and identified at 25 X and 50 X under a Wild binocular microscope. Seeds and other plant macrofossils were identified by comparison with published descriptions and keys (Montgomery 1977; Martin and Barkley 1961; Berggren 1981) and the herbarium material collection of the Paleoenvironmental Studies Laboratory, Department of Anthropology, University of Alberta.

Preliminary determinations of mollusca made by the author with comparison with published descriptions (Clarke 1981), were kindly verified by J. Van Es, Department of Zoology, University of Alberta.

4. Results

The three sites investigated for this study, Mitchell Lake, Strubel Lake, and Nordegg Pond, are all located in the area of the upper North Saskatchewan River Valley (Fig. 4.1). Since, as explained in the methods section, only samples below the Mazama tephra were analyzed, diagrams depicting sediment stratigraphy, numerical zonation, pollen percentages, and influx values extend only up to this tephra horizon.

4.1 Mitchell Lake

4.1.a Site Description

Mitchell Lake, (52^0 13' N, 115^0 00'30" W), is located at 1050 m above sea level, approximately 18 km SSW of the town of Rocky Mountain House, Alberta (Fig. 4.1). The area is within the Eastern Lowlands region of the Rocky Mountain Foothills of west central Alberta (Boydell 1978: Fig. 3), an area of transition to the plains further to the east. Mitchell Lake is an oblong lake oriented NW to SE in an elongate depression following the trend of a long ridge. The lake's dimensions are 300 m by 500 m, with an area of about 15 ha. The north side of the lake basin drops sharply to a maximum depth of 6 m, while the remainder of the basin slopes more gradually to depths of 3 to 4.5 m (Fig. 4.2). No streams enter the lake. Inflow to the lake is probably derived from surface runoff and groundwater flow.

Although located within the proposed boundary of the Athabasca till (Boydell 1978), Mitchell Lake was near the confluence of three differing ice sources during Wisconsinan times, Jackfish Creek till of Rocky Mountain provenance, Athabasca till of mixed provenance, and Sylvan Lake till of Laurentide provenance. This makes geological interpretations difficult, especially since much of the evidence of ice relationships is obscured by abundant glaciofluvial, glaciolacustrine, and aeolian deposits.

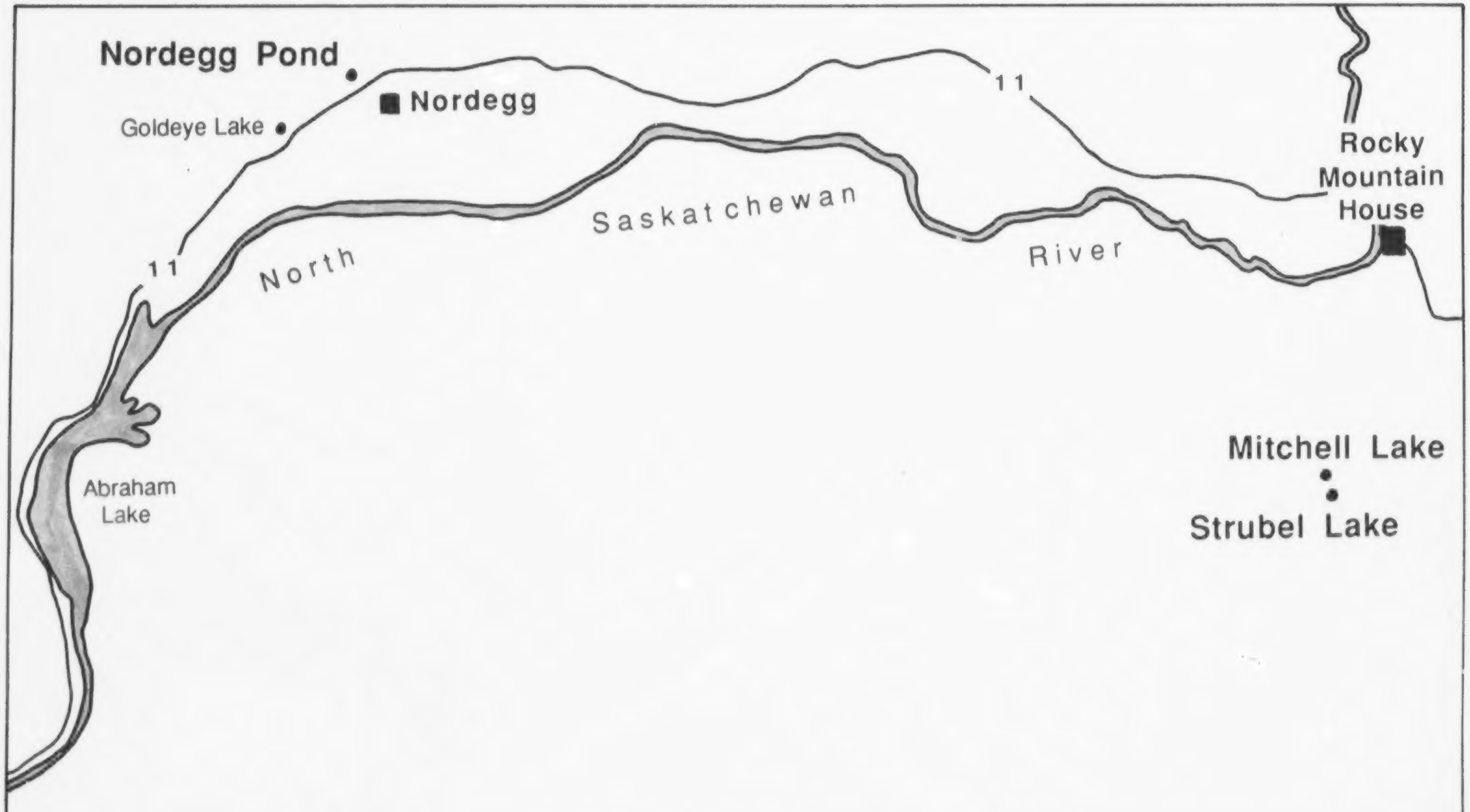

Nordegg Pond
Nordegg
Goldeye Lake
11
11
North
Saskatchewan
River
Rocky Mountain House
Abraham Lake
Mitchell Lake
Strubel Lake

Figure 4.1 Upper North Saskatchewan River Valley Location Map

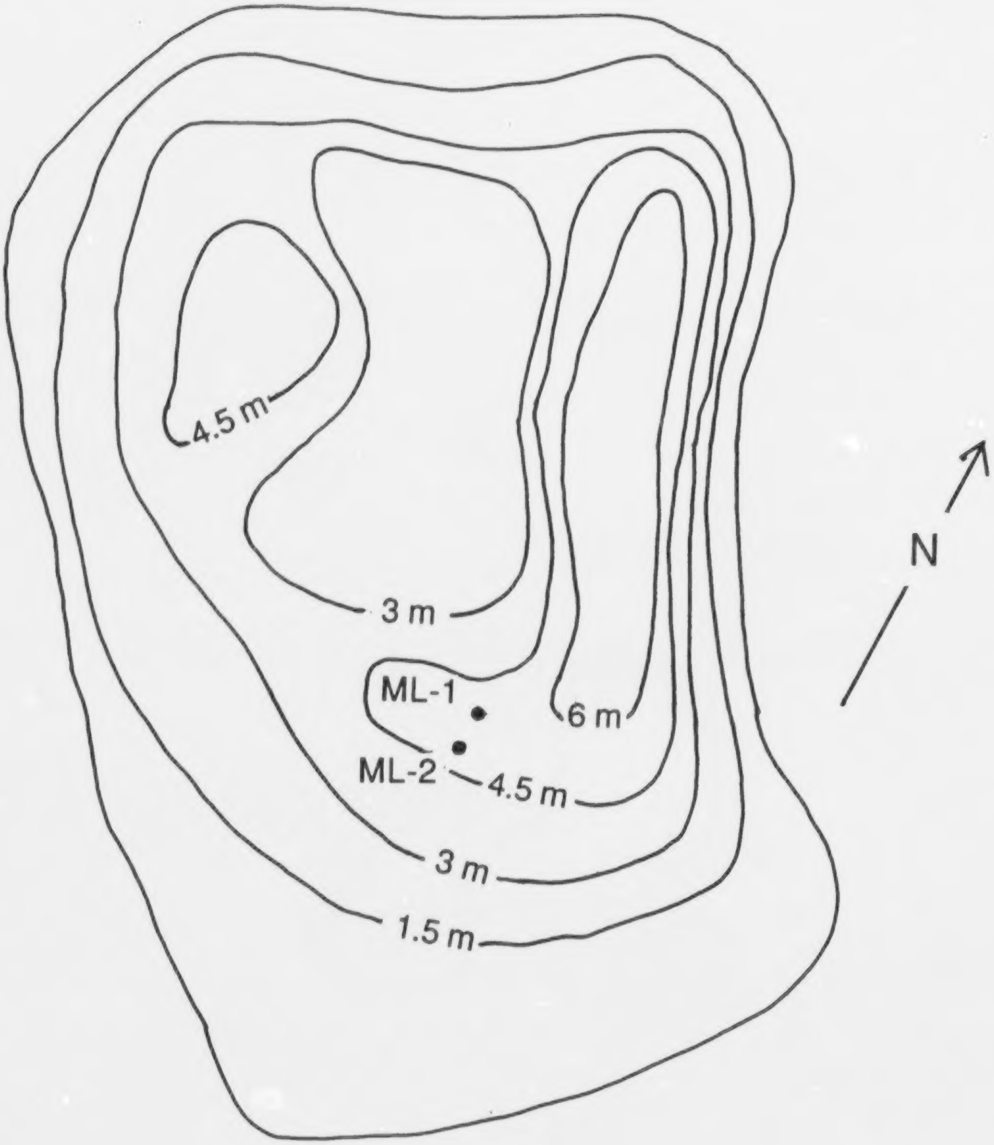

4.5 m
3 m
ML-1
6 m
ML-2
4.5 m
3 m
1.5 m
N

Figure 4.2 Mitchell Lake Bathometry and Coring Sites

The area around Mitchell Lake was originally mapped as aeolian sand with some ice-contact deposits (i.e., kame, kame moraine) nearby (Boydell et al. 1974). A recently published map of the area classifies the deposits immediately around the lake as ice-contact lacustrine and fluvial deposits likely formed in intermittent streams, supraglacial lakes, or at the edges of ice-floored proglacial lakes (Shetsen 1990). Shetsen's characterization more accurately reflects the nature of the deposits observed in road cuts and slumps near the lake, i.e., abundant gravel, sand, silt and clay, and local till, as opposed to the fine to medium grained aeolian sand proposed by Boydell (1978).

Although evident on topographic maps and airphotos (Fig. 4.3; Plate 4.1) of the area, the northwest and southeast trending depression and ridges adjacent to Mitchell Lake are not depicted on either of the maps of the surficial geology of the region. The elongate depression containing Mitchell Lake and an intermittent pond to the northwest is roughly parallel to the trend of North Prairie Creek (2 km to the southwest), which was the former route of a major ice-walled spillway between the Jackfish Creek and Athabasca ice lobes (Boydell 1978). Furthermore, in Boydell's (1978:7) description of the Northern and Eastern Lowlands region he notes that although the bedrock in the area is the relatively soft Paskapoo Formation, "the surface expression, while generally subdued, is characterized by several low, southeast trending bedrock ridges." Whether the ridge bounding Mitchell Lake is a former meltwater channel that drained meltwaters from the Athabasca ice lobe immediately to the northwest of the lake, a bedrock ridge mantled with glacially derived surficial deposits, or perhaps a postglacial drainageway cut into the glaciolacustrine sediments of Glacial Lake Caroline, is unresolved at this time.

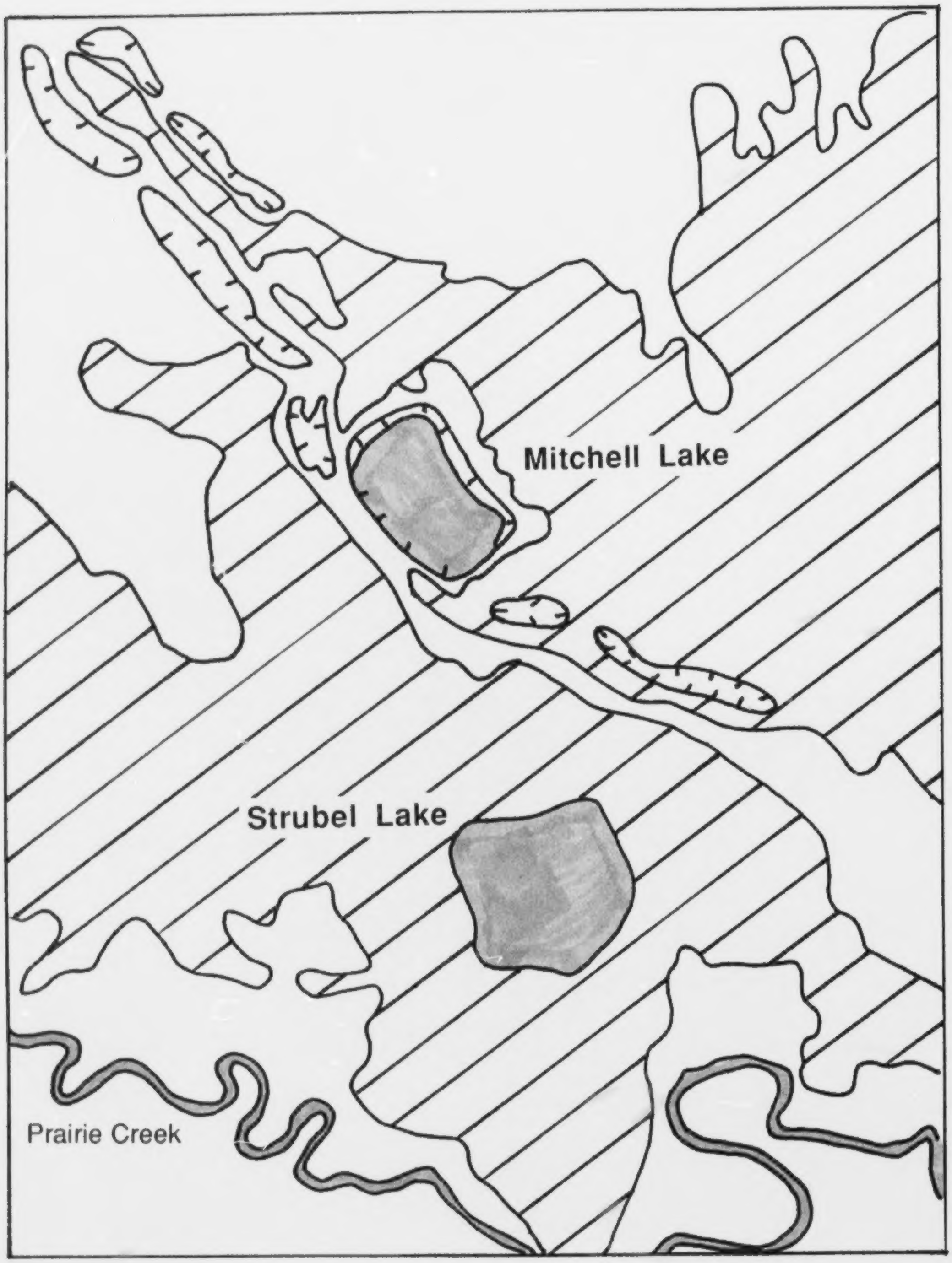

Mitchell Lake
Strubel Lake
Prairie Creek

Figure 4.3 Mitchell and Strubel Lake Regional Topography

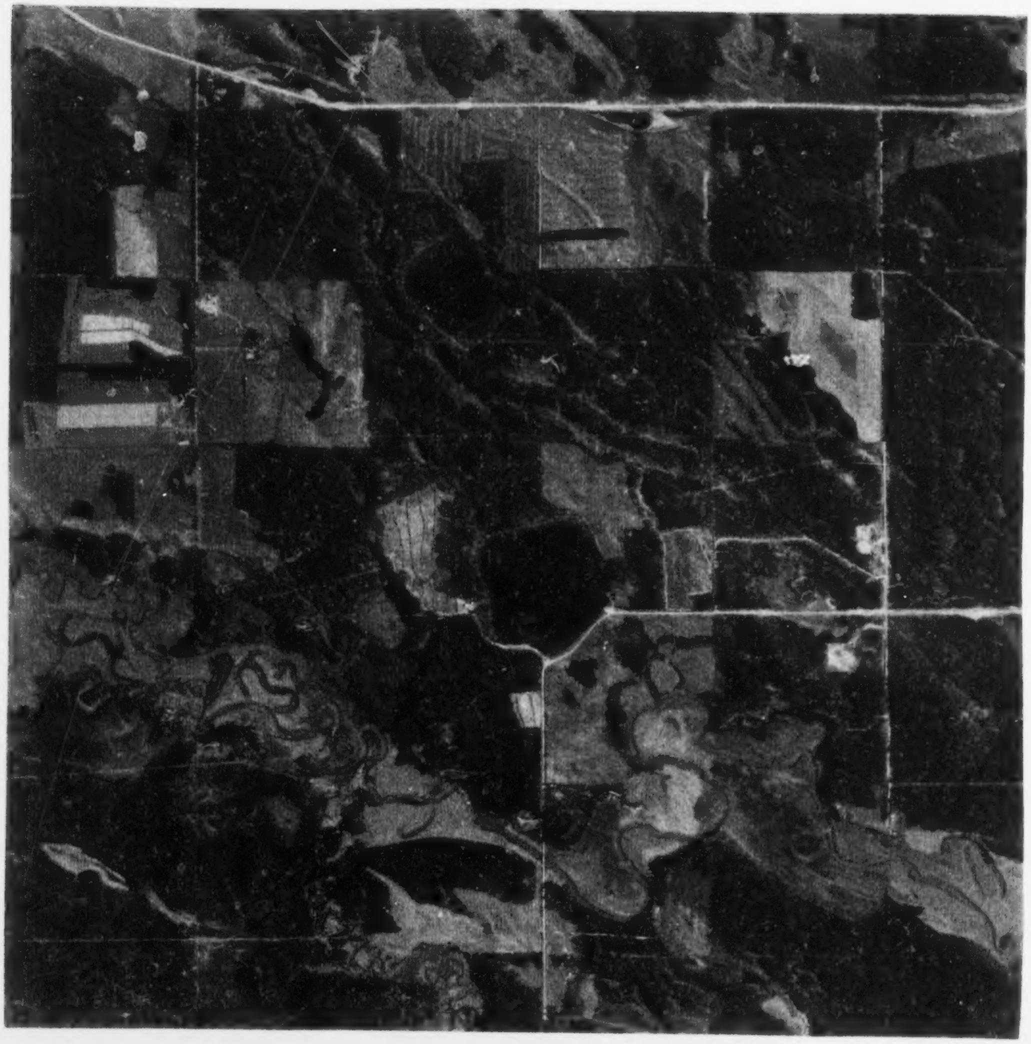


Plate 4.1 Air Photo of Mitchell and Strubel Lakes. Alberta Forestry, Lands and Wildlife Photograph.

Whatever the mode of formation of the surficial deposits, the timing of deposition is a separate matter. As in several other areas within the ice-free corridor, the glacial chronology in the vicinity of Mitchell Lake has varying interpretations. The Jackfish Creek till of Rocky Mountain provenance, Athabasca till of mixed provenance, and Sylvan Lake till of Laurentide provenance, which are believed to have coalesced and flowed southward along the foothills, possibly depositing the Erratics Train till and the Okotoks erratic, have been correlated to the late Wisconsinan (ca. 25,000 to 12,000 yr B.P.), by some investigators (Boydell 1978; R. Young et al. 1989; Kvill 1989; Rains et al. 1990).

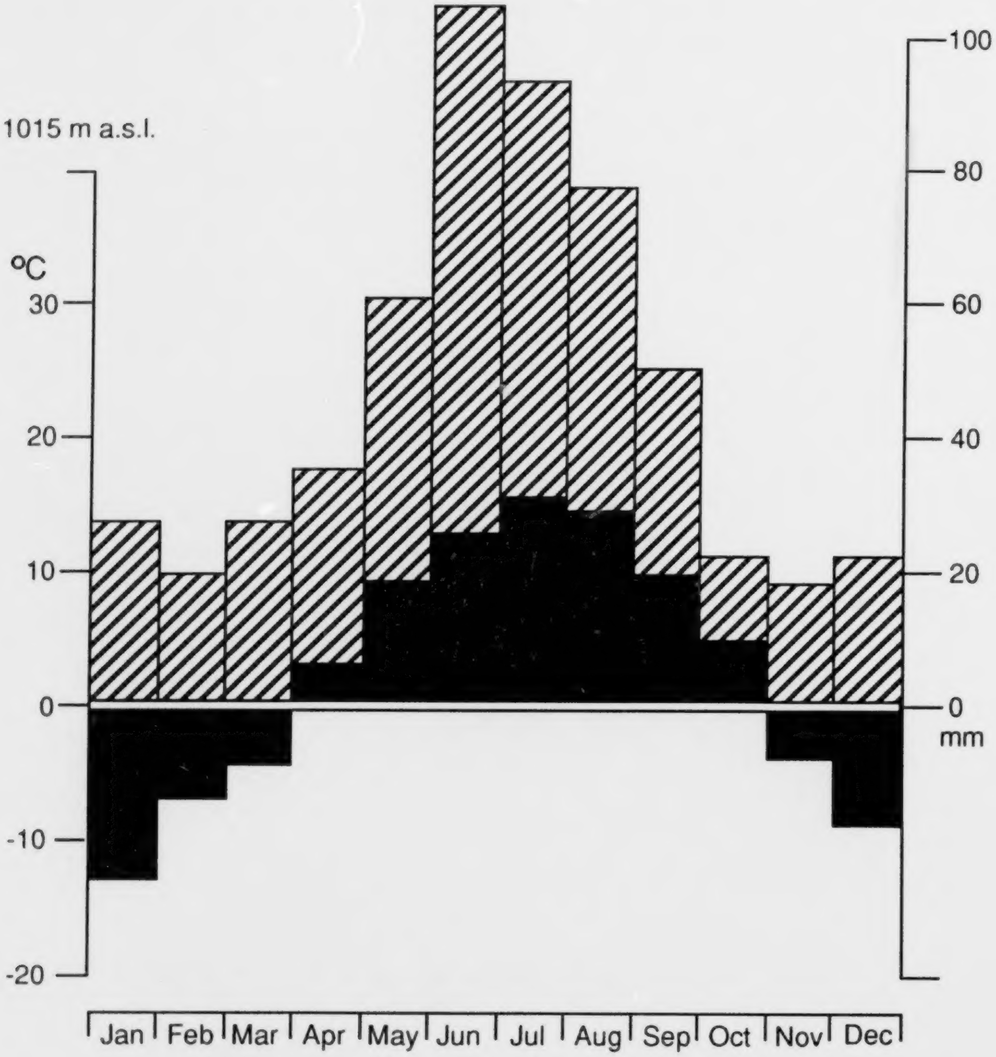
Such a correlation denies the existence of an ice-free corridor in the region until deglaciation was well underway. If this interpretation proves to be correct, the dates on vertebrate fauna from quarries in the Edmonton region indicating Mid-Wisconsinan ice free conditions as late as 22,000 (Burns 1989), and the date from Mitchell Lake indicating that Laurentide ice had retreated from the Rocky Mountain House area by ca. 18,000 years ago, imply a very short-lived Late Wisconsinan maximum of perhaps 3,000 to 4,000 years duration. If this were the case, Laurentide ice may have reached the Edmonton region just after 22,000 years ago, advanced approximately 200 km to the southwest to coalesce with Cordilleran ice ca. 20,000 years ago, and begun retreat and/or stagnation adequate to uncover the Mitchell Lake basin by ca. 18,000 B.P. Such an early date for initial deglaciation in the Rocky Mountain House area is not really that surprising considering that Mitchell Lake is only 4 km northeast of Boydell's (1978: Figs. 5,14) proposed zone of coalescence of the Laurentide and montane ice, and 6 km north of an ice-free zone between the two ice masses; and as such would have been in a position to be exposed at the very earliest stages of glacial retreat.

Alternatively, it appears to other researchers that the evidence indicates that the Jackfish Creek, Athabasca, and Sylvan Lake glaciers are probably pre-Late Wisconsinan age (Rutter 1984; Schweger 1985; Bobrowsky et al. 1989). In this scenario Late Wisconsinan Laurentide ice did advance to within 10 km east of the site, causing ponding and development of proglacial lakes, e.g., Glacial Lake Caroline; however, the influence of ice lobes to the west and northwest would have been much less, perhaps with lobes restricted to river valleys with much open land in the foothills.

Whether there was an extensive ice-free area in the region during the Late Wisconsinan or not, proglacial lakes and ice-contact deposits would have been part of the immediate environment. Observation of air photos suggests the existence of a stagnant ice-contact esker complex immediately northeast of Mitchell Lake. Florin and Wright (1969:699) note that stagnant ice frequently results in "formation of a complex of ice-contact features including mollusk-bearing lacustrine silts." The mollusc-rich sediments of Mitchell Lake may represent such an ice-contact lacustrine silt. Thus Mitchell Lake may have begun its existence within a stagnant ice-contact environment and/or as part of Glacial Lake Caroline.

The modern climate of the area is characterized as cool continental-temperate, with long cold winters and short cool summers. Climatic normals (Environment Canada 1982:155) are available for Rocky Mountain House. For the period 1951-1980, the mean January temperature was -13.0^{0} C, with a range of -43.9^{0} C to 15.0^{0} C. The mean July temperature was 15.3^{0} C with a range of 0.0^{0} C to 33.3^{0} C. The mean annual precipitation was 556 mm. Most precipitation occurs during the summer months (Fig. 4.4). The

Figure 4.4. Climatic Normals, 1951-1980, Rocky Mountain House



■ Mean Monthly Temperature

▨ Mean Monthly Precipitation

Plotted from values reported by Environment Canada (1982) area is dominated by Arctic air masses in winter and spring, whereas the summer is primarily influenced by Maritime air masses (Alberta Weather Centre 1989).

The vegetation of the area is typical of the transition between the southern margin of the boreal forest and the western parklands (Rowe 1972; Budd 1987), although North (1976) maps the region as an Aspen to Spruce ecotone between the boreal and subalpine forests. In the immediate vicinity of Mitchell Lake the dominant tree species are balsam poplar (*Populus balsamifera*) and aspen (*Populus tremuloides*), with some white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), and birch (*Betula papyrifera*).

4.1.b Sediment description

The sediment lithology of the Mitchell Lake core (Table 4.1) consists of organic or organic-rich sediments from 0 to 374 cm, marl or marly sediment between 374 and 405 cm, and increasingly inorganic clay, silt, and sand from 405 to the bottom of the core at 575 cm. Maximum organic matter percentages correspond to the organic rich sediments in the core, while the maximum carbonate percent values correspond to the marl section of the core (Fig. 4.5). Below 430 cm, carbonates, organic matter, and pollen concentration and influx decrease to low levels. Low moisture content at the base of the core may be a reflection of increased density due to sediment compaction (Adams and Duthie 1976:24).

4.1.c Radiocarbon Dating and Core Chronology

A chronology for Mitchell Lake was established using radiocarbon dates (Table 4.2) and the accepted ages of Mt. St. Helen's Y (3400 B.P.), and Mazama (6800 B.P.) tephras (Mullineaux 1974; Bacon 1983). Three curve-fitting methods were considered for calculating sedimentation rates and

Table 4.1. Lithologic Units of Mitchell Lake[a]

Depth (cm)	Description and Color[b]	Lower Contact	Remarks
0-240	Gyttja, 10YR 2/2, 10YR 3/2, 10YR 2/1	Gradational over 20cm.	Loose to firm, moist, diffuse bands. Tephra unit at: 117-118cm. Coarse stem fragments at 235cm.
240-374	Very organic silt, 10YR 3/2, 10YR 2/1, 2.5Y 3/2	Very sharp.	Firm, faint bands. Tephra unit at: 286-290cm, (with ash stringers to 312cm) Coarse plant remains 283-285cm. Several pebbles at 270cm.
374-385	Marl, 2.5Y 5/2, 2.5Y 6/2, 2.5Y 4/2, 10YR 3/2	Sharp.	Firm, dry, distinct bands.
385-405	Marly clay, 10YR 4/1	Gradational over 10cm.	Firm. Abundant *Psidium*, esp. 395-400cm. Cara? at 405cm.
405-430	Clay, 10YR 4/1	Sharp.	Very firm.
430-495	Interbedded silty clay and sand, 10Yr 4/1	Sharp.	
495-575	Sand, 10YR 4/1		Thin clay laminae[c] occur between: 517-529, 539-547, and 568-574cm.

[a] Core ML-2 used for sediment description.

[b] Munsell color notation (GSA Rock Color Chart, 1975)

[c] After Mehringer et al. (1977), bands refer primarily to difference in color whereas laminations differ primarily in texture.

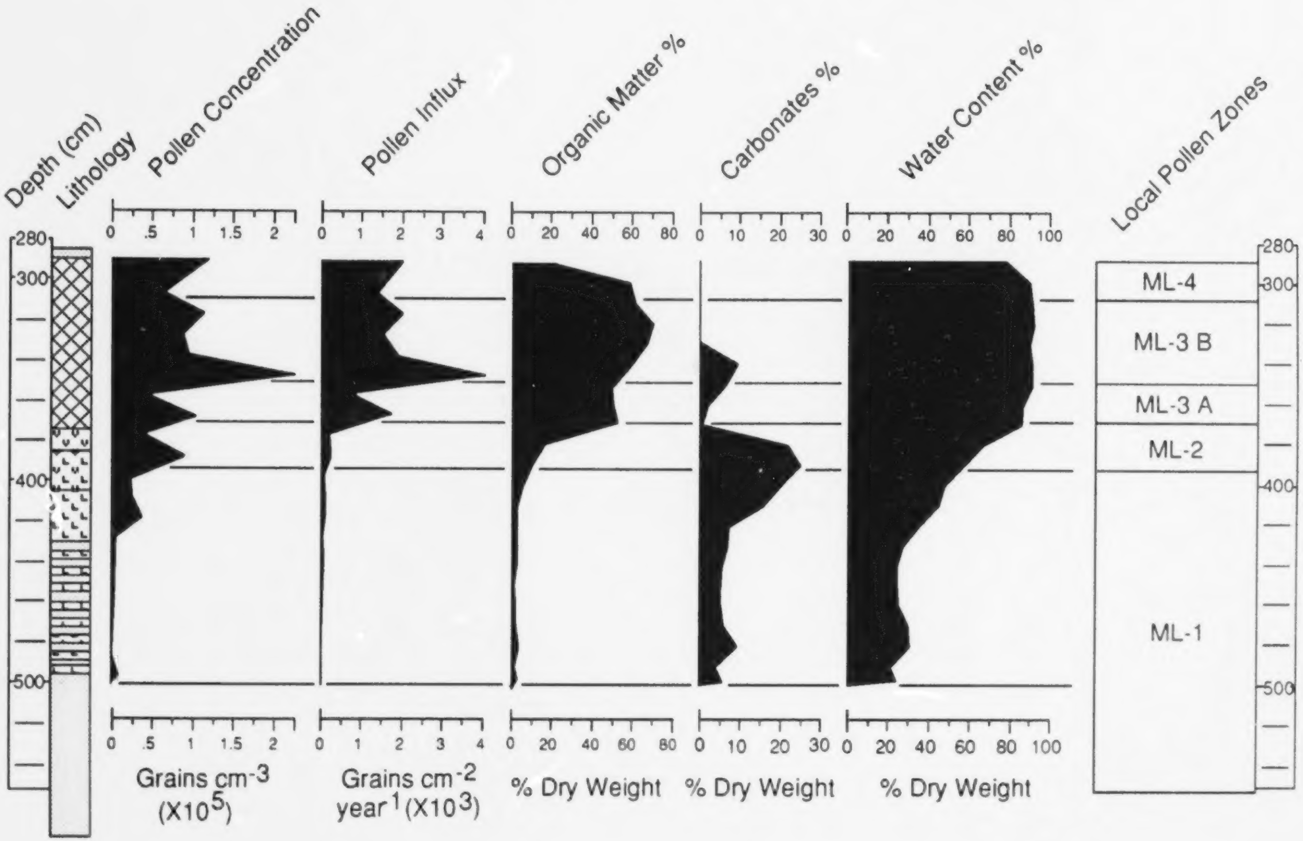


Figure 4.5. Sediment stratigraphy at Mitchell Lake in relation to local pollen zones, total pollen concentration and pollen-influx curves, percentage loss-on-ignition curves (organic matter and carbonates) and percent water content.

Table 4.2. Mitchell Lake Radiocarbon Dates

Depth (cm)[a]	Material	Age (yr B.P.)[b]	Lab No.[c]
368-369	Gyttja	11,110 +/- 110	TO-572
395-387	*Sphaerium* & *Psidium* shells	14,740 +/- 13	TO-573
399-401	*Sphaerium* shells	17,960 +/- 160	TO-574

a, Depth below mud surface on composite core.
b, Uncorrected radiocarbon years.
c, TO, Isotrace Laboratory, University of Toronto.

determining ages of nondated portions of the core: simple linear regression, quasi-Hermite piecewise polynomial spline approximation (De Boor 1978), and linear interpolation.

The first two methods yielded smoother sedimentation rates and provided third degree polynomial equations and derivatives from which influx rates for individual samples could be calculated. However, while individualized rates may seem more precise, whether increased accuracy accompanies this precision is questionable. It was felt that as the locations of the Mitchell Lake radiocarbon dating samples were chosen at actual changes in sedimentation, a method that smoothed or averaged these differences was subtracting rather than adding useful information. Therefore linear interpolation between dates was used to plot radiocarbon age versus sediment depth (Fig. 4.6). Dates for events occurring at points in the core other than those sampled were extrapolated from the radiocarbon dates using sedimentation rates.

4.1.d Discussion of dates

Dating lake sediments in the ice-free corridor area is often problematic as the region is underlain by carbonaceous bedrock, often reworked into surficial deposits, which are the source of "old" carbon that dilutes the local ^{14}C:^{12}C ratio (Lowe and Walker 1984:237; MacDonald et al. 1987:837). Coal-rich sediments and organic material from older deposits also enrich lakes with high proportions of inert carbon (Nambudiri et al. 1980:123; Hickman et al. 1984:1438). These additions of ^{14}C deficient carbon are often present in lake sediments in the corridor region and can result in apparent ages of samples that date thousands of years older than their true age.

The immediate post-glacial environment is particularly vulnerable to

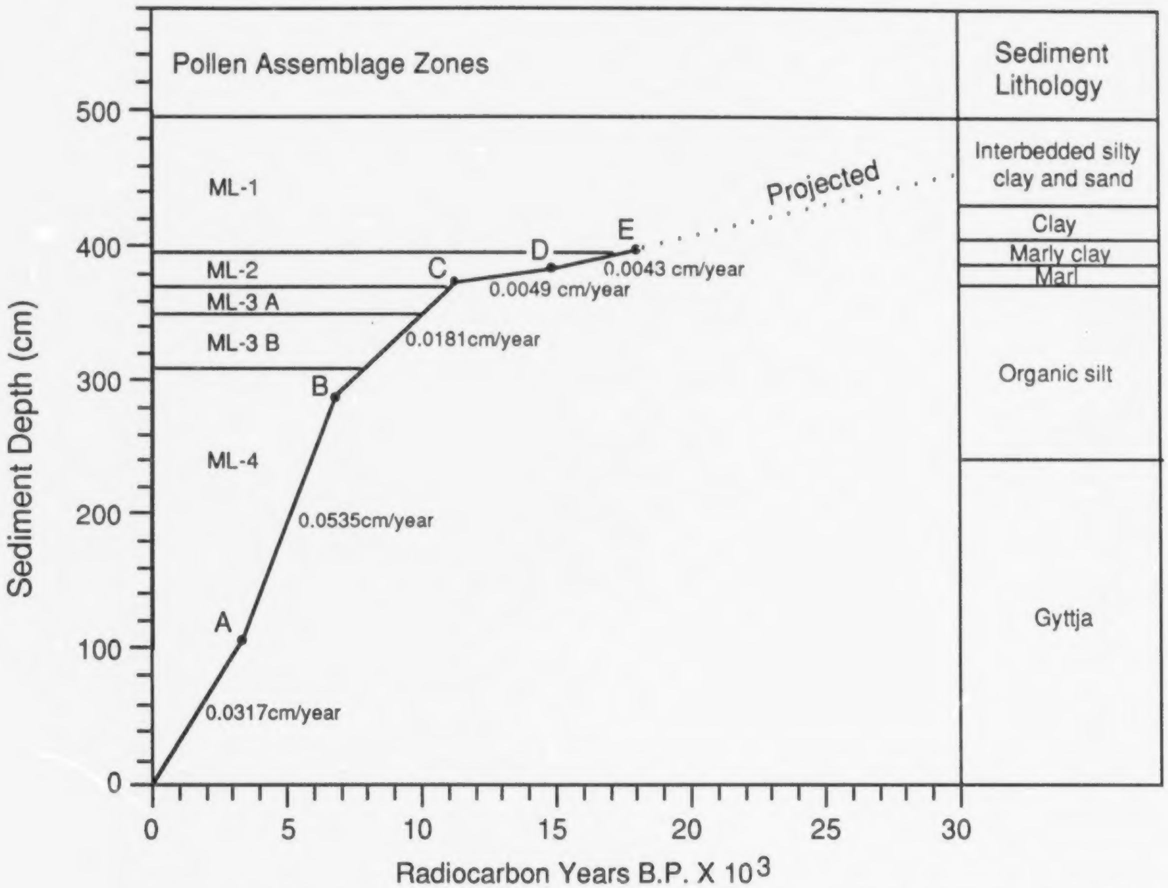


Figure 4.6 Mitchell Lake Sedimentation. A, Mt.St. Helen's Y; B, Mazama;C, TO-572; D, TO-573, E, TO-574

error caused by the influence of old carbon. The combination of dissolved carbonates and other inorganics washing in from bare mineral soils and a sparse vegetation cover results in sediments that are high in inorganics and low in organic carbon. It is now recognized that dates of sediments containing less than 2% organic carbon are likely to be in error (Bjorck and Hakansson 1982:148; King 1985:168).

Some dating problems can be avoided by dating macrofossils by accelerator mass spectrometry (Shotton 1972:460: White et al. 1985:182). Although terrestrial macrofossils are preferred, they were not evident in the Mitchell Lake cores. Two radiocarbon dates from Mitchell Lake were determined on *Sphaerium* and *Psidium* shells and one on gyttja. Terrestrial macrofosils are preferred because aquatic organisms may incorporate particulate or solutional carbon from old sources either during growth (Shotton 1972:460; Barnosky et al. 1987a:268), or as secondary contamination (Berglund 1986:291). In molluscs, the contamination due to incorporation of old carbon in the carbonate matrix may be controlled to some extent by choosing species that exhibit a "tight" shell matrix (Mangurud 1972:158; Lowe and Walker 1984:238). Both *Sphaerium* and *Psidium* exhibit such a matrix, thus minimizing contamination caused by initial synthesization of skeletons from old carbonates.

In addition, the *Sphaerium* and *Psidium* samples fulfilled all criteria (Mangerud 1972:158; Fillion et al. 1981:107) for minimizing secondary contamination, being very well preserved whole valves with periostracum intact and with no evidence of reworking or redeposition. Such shells may yield reliable dates that are generally more accurate than total organic matter dating of lake sediments (Fillion et al. 1981:105). Thus the dates on these shells of 14,740 +/- 130 yr B.P. (TO-573) and 17,960 +/- 160 yr B.P. (TO-574) are accepted as maximum ages.

Finally the 11,110 +/- 110 yr B.P. (TO-572) date on gyttja is assumed to be correct as it is in correct chronological order with the other dates and it correlates well with dates elsewhere in Alberta for the first appearance of *Picea*. The gyttja sample comes from an organic rich layer, with an organic matter content of 52%, thus avoiding problems associated with low organic matter; furthermore no visible coal particles or pre-Quaternary palynomorphs were observed in the gyttja.

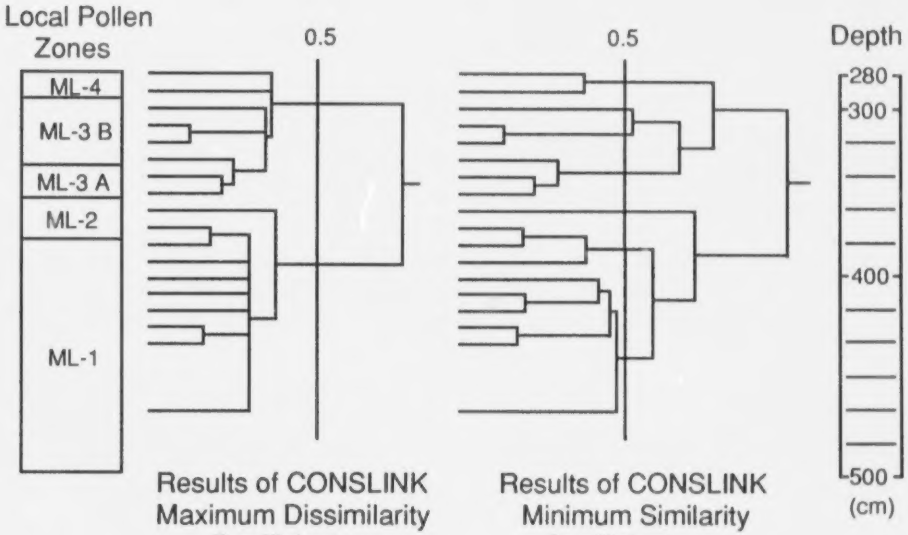
4.1.e Pollen Zone Descriptions

Pollen data are plotted as percent (Fig. 4.7) and influx values (Fig. 4.8) within zone boundaries determined with the aid of the SPLITINF, SPLITLSQ, and CONSLINK programs (Fig. 4.9). Although pollen bearing sediment extended to 552 cm, only one sample below 446 cm had a pollen sum over 200. As sums less than this are inadequate for statistical analysis, all samples with sums less than 200 are not shown on the diagrams or considered in the interpretation.

Pollen Zone ML-1 (Artemisia-Gramineae Zone), 496 - 392 cm

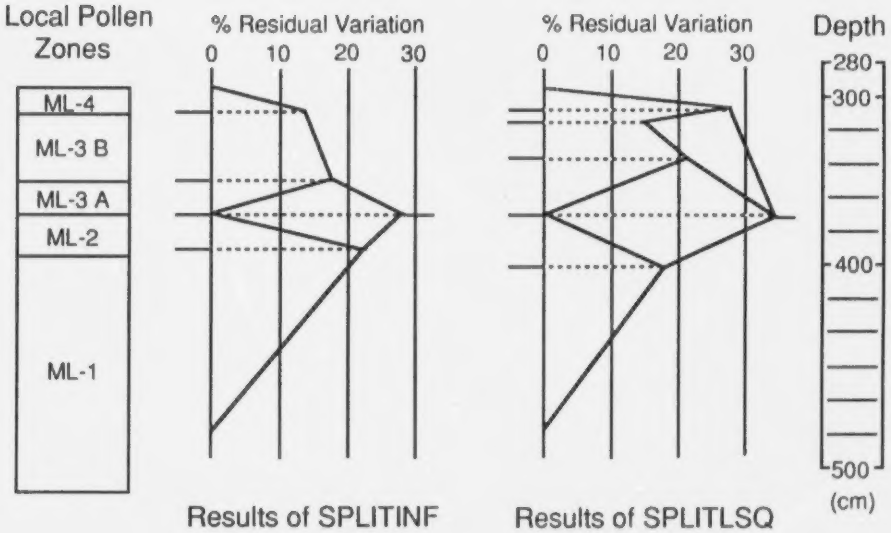
Description: Zone ML-1 is dominated by high percentages of nonarboreal taxa. *Artemisia* pollen predominates, ranging from 38 to 78 percent. Gramineae pollen is also at its maximum with values of 5 to 20%. *Salix* is abundant with values of 5 to 15%. *Pinus* values range from 5 to 20%. Cyperaceae and Chenopodiaceae-*Amaranthus* occur consistently with frequencies of 2 to 8%. *Betula, Alnus, Populus,* Tubuliflorae high spine and low spine, *Sarcobatus,* Cruciferae, Rosaceae, and *Epilobium* occur consistently in low (1 to 2%) amounts. *Epilobium, Ranunculus,* and *Triglochin* are restricted to this zone.

Figure 4.9 Numerical Zonation of Mitchell Lake as calculated from percentages of *Pinus, Picea, Betula, Alnus, Salix, Artemisia,* Gramineae, and Chenopodiaceae-*Amaranthaceae.*



Results of CONSLINK Maximum Dissimilarity Coefficient

Results of CONSLINK Minimum Similarity Coefficient



Results of SPLITINF Plotted to 14.29 %

Results of SPLITLSQ Plotted to 14.78 %

Contacts: The lower boundary is the base of pollen-bearing sediment. The upper boundary is placed where *Betula* rises from 0 to 10%, at 392 cm.

Radiocarbon Age: The age of this zone is extrapolated at greater than 18,000 to 16,100 years B.P.

Influx: Zone values range from 9 to 162 and average 63 grains cm^{-2} $year^{-1}$.

Remarks: Carbonate values are very high at the upper end of this zone, reflecting both the marly nature of the sediment and the abundant mollusca.

Comparisons: Zone ML-1 is comparable with similar published assemblages from Alberta, in particular Zone CB-3 from Chalmers Bog (Mott and Jackson 1982).

Pollen Zone ML-2 (*Betula-Salix* Zone), 392 - 372 cm

Description: Zone ML-2 is dominated by *Betula*, with values to 32%. Gramineae and *Artemisia* decrease in percent throughout the zone. Cyperaceae, Chenopodiaceae-*Amaranthus, Alnus,* Tubuliflorae high spine and low spine, *Populus,* Cruciferae, and *Plantago* all reach maximums in this zone of 2 to 5%. Frequencies of *Salix* and *Pinus* are similar to those in ML-1. The sole occurance of *Gentianella* (less than 1%) is in this zone.

Contacts: The upper boundary is placed where *Betula* decreases from 32 to 7%, while *Picea* increases from less than 1 to 12% at 372 cm.

Radiocarbon Age: The age of this zone is extrapolated from 16,100 to 11,400 years B.P.

Influx: Zone values range from 214 to 393 and average 303 grains cm^{-2} $year^{-1}$.

Remarks: While percent values for *Artemisia* show a significant decrease, influx values for *Artemisia* hold steady, even showing an increase at the beginning of the zone. Carbonate percent decreases while organic matter content increases from the middle to the top of this zone.

Comparisons: Zone ML-2 is comparable with similar assemblages from Alberta, including Fairfax Lake (Kvill 1985) and Goldeye Lake (Hickman and Schweger, in preparation).

Pollen Zone ML-3 (*Picea* Zone), 372 - 311cm

Description: Zone ML-3 shows the abrupt increase of *Picea* to a maximum value of 43%. *Alnus,* and *Corylus* occur consistently with values of 3 to 7 and 2 to 3% respectively. *Salix,* Gramineae, *Artemisia*, and Cyperaceae decrease to minimum values of 1 to 2%. *Pinus* ranges from 21 to 42%. Liguliflorae and *Geranium*, at very low values (less than 1%), are restricted to this zone.

Contacts: The upper boundary is placed where *Picea,* decreasing from 36 to 11%, drops below *Pinus*, which increases from 35% to a maximum of 64%, at 311 cm.

Subzones: The following subzones are delimited:

ML-3A, 372-351cm. In this section of the zone *Betula* pollen decreases to very low values both in percent (2 to 4%) and influx (approximately 30 grains cm^{-2} $year^{-1}$), while *Alnus* reaches its maximum of 7%.

ML-3B, 351-311cm. *Betula* pollen is the most abundant arboreal pollen, rising in a second peak to a maximum of 50%. Tubiliflorae high spine, Chenopodiaceae-*Amaranthus, Thalictrum,* and Cyperaceae pollen values are lower than in ML-3A.

Radiocarbon Age: The age of this zone is extrapolated at 11,400 to 8,000 years B.P., with the subzone ML-3A/ML-3B boundary dated at 10,200 years B.P.

Influx: Zone values range from 818 to 4010 and average 2000 grains cm^{-2} $year^{-1}$.

Remarks: Both percentages of total arboreal pollen and total pollen influx increase abruptly at the beginning of this zone. The *Betula* peak of subzone ML-3B displays significantly higher pollen influx values than the first *Betula* peak in zone ML-2.

Pollen Zone ML-4 (*Pinus* Zone), 311 - 295 cm

Description: Zone ML-4 is characterized by an abrupt increase in *Pinus*, which with values of 42 to 64% is the most abundant pollen type. Other significant taxa include *Picea* (11 to 13%), *Betula* (8 to 20%), and *Alnus* (5%).

Salix, *Corylus*, Gramineae, *Artemisia*, Chenopodiaceae-*Amaranthus*, *Thalictrum*, and Cyperaceae all have values of 1 to 2%.

Contacts: The upper boundary is placed at the lower boundary of ash streamers extending from the Mazama ash layer at 285-290 cm, although presumably the zone extends upward throughout the nonanalyzed section of the core.

Radiocarbon Age: The age of this zone is extrapolated at 8,000 to 7,000 years B.P.

Influx: Zone values range from 1300 to 2194 and average 1747 grains cm^{-2} $year^{-1}$.

4.2 Strubel Lake

4.2.a Site Description

Strubel Lake, (52°12'N, 115°00'W), is in the Eastern Lowlands region of the Rocky Mountain Foothills (Boydell 1978: Fig.3) of west central Alberta, an area of transition to the plains to the east at 1080 m elevation. Strubel Lake is 700 to 800 m SE of Mitchell Lake, approximately 20 km SSW of the town of Rocky Mountain House (Fig. 4.3 and 4.1). The lake is 500 m by 600 m with an area of about 30 ha. No streams enter the lake. Most of the lake basin slopes gradually to depths of 7.5 to 9 m, while the northwest side of the basin exhibits steeper slopes to maximum depths of 12.6 m (Fig. 4.10).

Strubel Lake occupies a depression formed in aeolian sands (Boydell et al. 1974: Shetsen 1990) likely derived from the delta of Glacial Lake

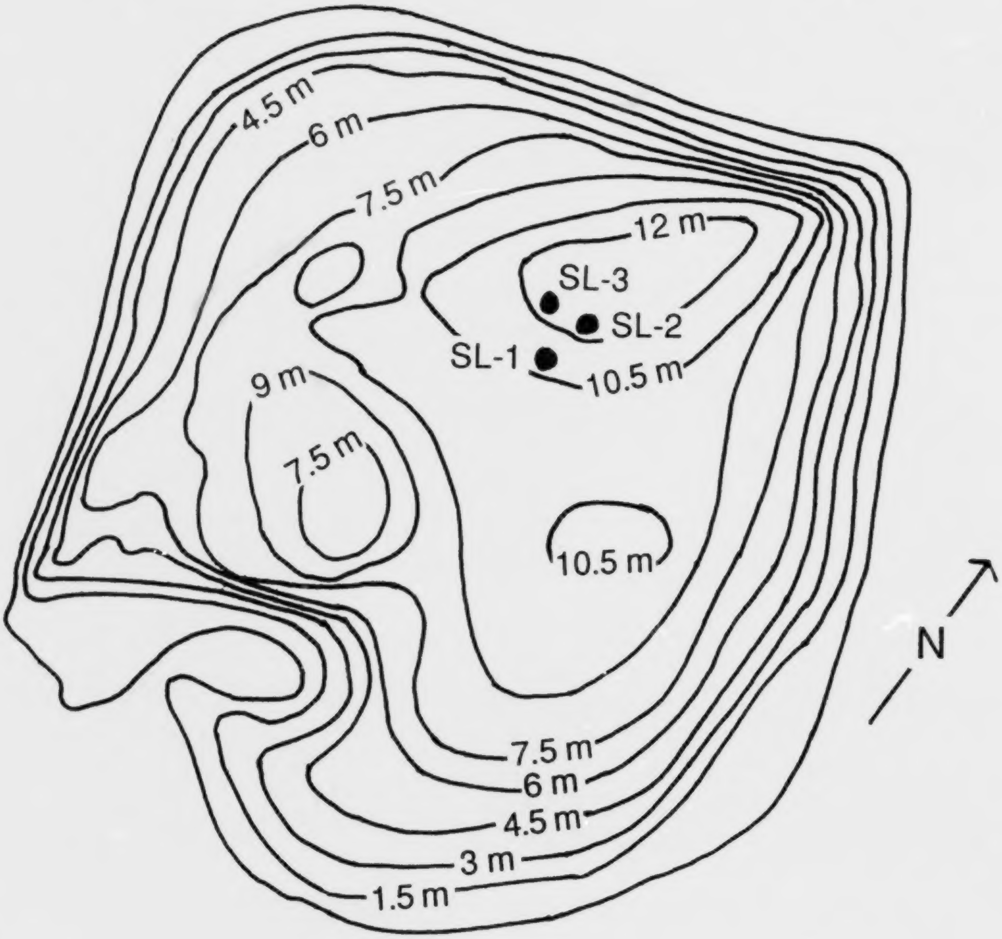

4.5 m
6 m
7.5 m
12 m
SL-3
SL-2
SL-1
10.5 m
9 m
7.5 m
10.5 m
N
7.5 m
6 m
4.5 m
3 m
1.5 m

Figure 4.10 Strubel Lake Bathometry and Coring Sites

Caroline. The basin would have been open to sedimentation following the drainage of Glacial Lake Caroline, considered by Boydell (1978) to have been a late Wisconsinan event associated with retreat from the Sylvan Lake (Laurentide) Moraine.

The climate of the area is characterised as cool continental - temperate, with long cold winters and short cool summers. Climatic normals (Environment Canada 1982:155) are available for Rocky Mountain House and have already been discussed in the description of Mitchell Lake.

Like Mitchell Lake, Strubel Lake is within the transition zone between the western boreal forest and the parklands. In addition, vegetation around Strubel Lake reflects influences of local topography and drainage. In the immediate vicinity of the lake the dominant tree species are white spruce (*Picea glauca*), aspen (*Populus tremuloides*), and birch (*Betula papyrifera*). There are large concentrations of pine (*Pinus contorta*) on the dunes immediately east of the lake. Willow (*Salix*) is found close to the water with a large variety of understory herbs and shrubs.

4.2.b Sediment description

In general the core consists of organic or organic rich sediments from 0 to 330 cm and increasingly inorganic silt and clay from 330 to 475 cm (Table 4.3). The maximums in pollen concentration and organic matter percent clearly correspond to the organic-rich section of the core, with all values except carbonates decreasing in the clay rich section of the core (Fig. 4.11). The water content percentage curve is consistent with compaction of the deepest sediments; older sediments being generally denser and/or more compact (Adams and Duthie 1976: 24). Pyrite precipitates occurring as microscopic nodules of 2 to 15 microns occur throughout the core but are especially abundant between 368 and 388 cm.

Table 4.3. Lithologic Units of Strubel Lake[a]

Depth (cm)	Description and Color[b]	Lower Contact	Remarks
0-200	Gyttja, 10YR 2/2, 10YR 3/2	Gradational over 20 cm.	Loose to firm. Tephra unit at: 123-124 cm. Mottling 10YR 2/2 170-188 cm.
200-330	Organic silt, 2.5Y 3/2	Sharp.	Firm.Diffuse to distinct bands[c] ranging in color from 10YR 3/2 to 10YR 3/1. Tephra unit at: 276-280 cm.
330-368	Silty clay, 10YR 3/1,	Sharp.	Firm. Faint bands of 10YR 3/2, at 363-369 cm. *Stagnicola* 362-368cm
368-475	Clay, 10YR 4/1,		Firm. Thin (<1cm) sand laminae[c] occur between 413-430 and 451-458 cm. Sand lens at: 435-440, 465-475 cm. Abundant Pyrite nodules 368-388 cm.

[a] Core SL-1 used for sediment description.

[b] Munsell color notation (GSA Rock Color Chart, 1975)

[c] After Mehringer et al. (1977), bands refer primarily to difference in color whereas laminations differ primarily in texture.

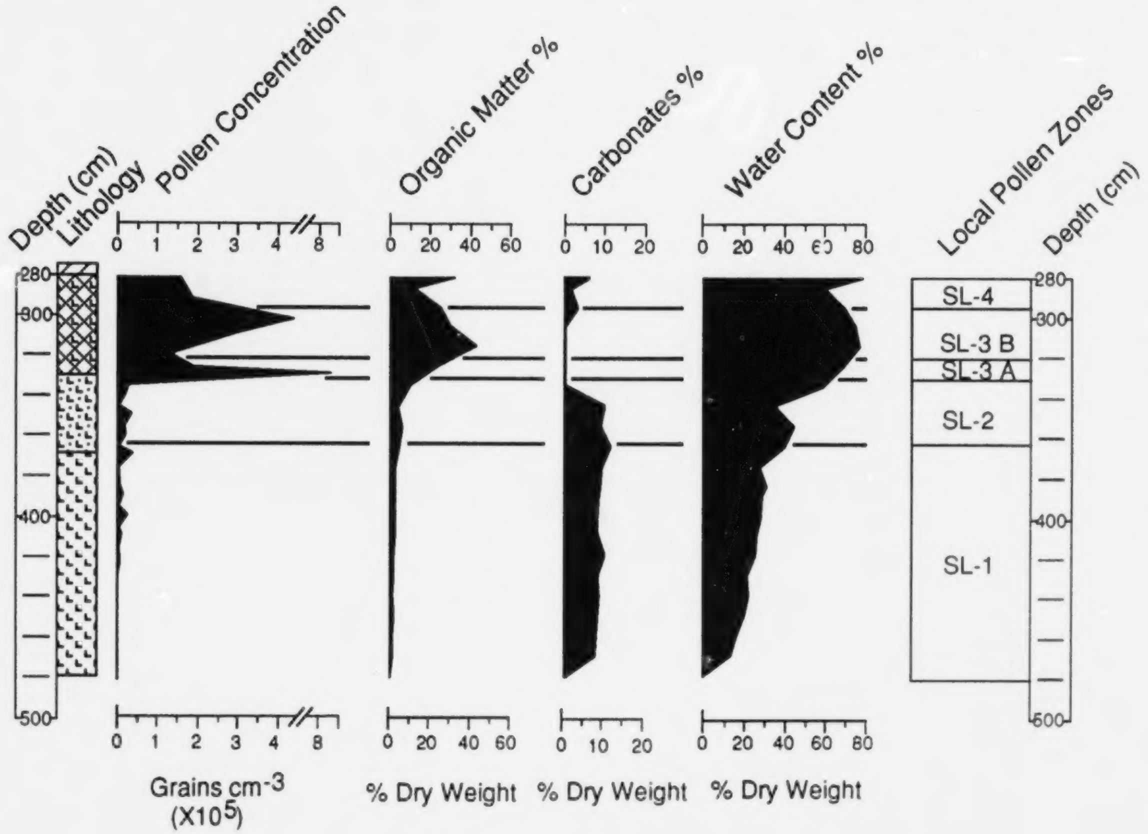


Figure 4.11. Sediment stratigraphy at Strubel Lake in relation to local pollen zones, total pollen concentration,percentage loss-on-ignition curves (organic matter and carbonates) and percent water content.

4.2.c Radiocarbon Dating and Core Chronology

The chronology of Strubel Lake is not firmly established due to rejection of the radiocarbon dates. The reliable date of 6800 B.P. for the Mazama tephra (Bacon 1983)) and comparisons with the pollen zones of nearby Mitchell Lake provide the only chronological control.

4.2.d Discussion of Dates

The Strubel Lake radiocarbon dates (Table 4.4) were rejected for several reasons. The dates, 21,800+/-570 B.P. and 29,000+/-1260 B.P. are much older than other dated lakes in the region and thus raise the possibility of error. Both samples were bulk lake-sediment, largely inorganic clay, with amounts of organic carbon less than 2%, which as previously discussed, leads to unreliable dates. The smaller the amount of carbon, the larger the effect of a potential contaminant. In addition, small black fragments presumed to be coal were found in the coarse mineral fraction of adjacent pollen samples and were visible as semi-transparent amber-colored shards under the light microscope.

Attempts to remove or at least quantitatively measure the contamination were unsucessful because of the large size variance of the coal fragments, their specific density overlapping that of pollen, and the fact that any solvents that could dissolve coal, e.g., Perideen (Koropchuk 1989, personal communication), also would destroy other organics including the pollen. The method of using the ratio of microfossils of pre-Quaternary age to those of Quaternary age as a guide to the amount of contamination (Nambudiri et al. 1980) was not applicable due to the absence of pre-Quaternary fossil pollen and spores. As discussed elsewhere, the solution to this problem is the dating of terrestrial macrofossils by accelerator mass spectrometry.

Table 4.4. Strubel Lake Radiocarbon Dates

Depth(cm)[a]	Material	Age (yr B.P.)[b]	Lab No.[c]
392-395[d]	Lake sediment	21,800 +/- 570	GSC-4220
458-463	Lake sediment	29,000 +/- 1260	GSC-4218

a, Depth below mud surface on composite core.
b, Uncorrected radiocarbon years.
c, GSC, Radiocarbon Dating Laboratory, Geological Survey of Canada
d, Includes correlative segments of 3 cm each from three duplicate cores.

4.2.e Pollen Zone Descriptions

Pollen data are plotted as percent (Fig. 4.12) and concentration values (Fig. 4.13) within zone boundaries determined with the aid of the SPLITINF, SPLITLSQ, and CONSLINK programs (Fig. 4.14). Although pollen bearing sediment extends to 473 cm, all samples below 408 cm had sums less than 200 and are not shown on the diagrams.

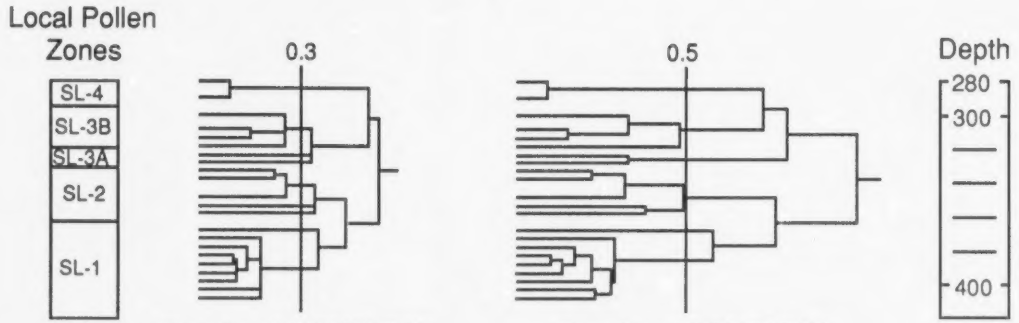
Pollen Zone SL-1 (*Artemisia*-Gramineae Zone), 408 - 363 cm

Description: Zone SL-1 is dominated by high percentages of nonarboreal taxa. *Artemisia* pollen predominates, with maximum values of 24 to 62%. Gramineae pollen is also at a maximum with values of 13 to 43%. Cyperaceae is abundant with values up to 25% (calculated outside sum). The following arboreal taxa are present in low but consistant amounts: *Pinus* 5 to 26%, *Salix* 2 to 9%, *Populus* 1 to 7%, *Picea* and *Alnus* <1 to 4%, and *Betula* <1 to 2%. Other taxa that consistently occur in low amounts are *Anemone* and Chenopodiaceae-*Amaranthus,* (<1 to 3%), Tubuliflorae high spine and low spine, *Sarcobatus,* and Cruciferae (<1 to 2%), and *Shepherdia canadensis, Juniperus, Ceonothus,* and *Thalictrum* (<1 to 1%). *Plantago, Galium, Epilobium, Lathyrus, Astragalus,* and *Potentilla* occur in values <1%. Sporadic low occurrences of Leguminosaceae, *Actaea, Ranunculus, Spirea,* and Compositae are confined to this zone.

Contacts: The lower boundary is the base of pollen-bearing sediment. The upper boundary is placed where Artemisia decreases to 40% at 363 cm.

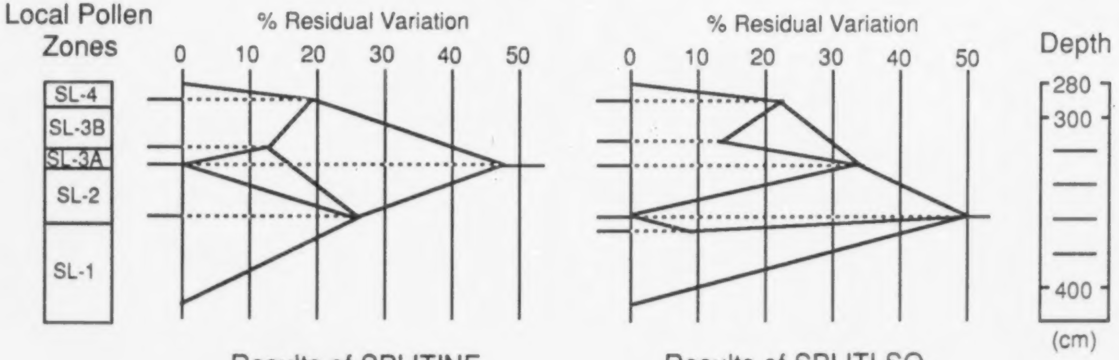
Radiocarbon Age: As discussed above, radiocarbon dates on Strubel Lake sediment were rejected. However, ML-1, the comparable zone at nearby

Figure 4.14 Numerical Zonation of Strubel Lake as calculated from percentages of *Pinus*, *Picea*, *Betula*, *Alnus*, *Salix*, *Populus*, *Corylus*, *Artemisia*, and Gramineae.


Local Pollen Zones
SL-4
SL-3B
SL-3A
SL-2
SL-1
0.3
0.5
Depth
280
300
400
(cm)

Results of CONSLINK Maximum Dissimilarity Coefficient

Results of CONSLINK Minimum Similarity Coefficient



Results of SPLITINF Plotted to 13.02 %

Results of SPLITLSQ Plotted to 9.79 %

Mitchell Lake, is estimated to date from greater than 18,000 to 16,100 yr B.P. These dates likely hold for Strubel Lake as well.

Influx: Influx values were not determined due to lack of reliable dates. Pollen concentration values range from 2,068 to 41,423 and average 10,755 grains cm^{-3} year^{-1}.

Remarks: *Eleagnus, Erigonum,* and *Castilleja* also occur only in this zone. They are not shown as all samples with sums <200 grains were left off the pollen diagram. There is a significant amount of degraded *Artemisia* pollen (ratio degraded/non-degraded of 16:1 to 46:1), in the lowermost samples.

Comparisons: Zone Sl-1 is nearly identical with Zone ML-1 of nearby Mitchell Lake (this work). In addition SL-1 is comparable to similar assemblages from Alberta, including zones CB-3 from Chalmers Bog (Mott and Jackson 1982) and GL-1 from Goldeye Lake (Schweger, in preparation).

Pollen Zone SL-2 (*Betula-Salix* Zone), 363 - 330.5 cm

Description: Zone SL-2 is dominated by *Betula*, with values of 20 to 52%. Gramineae and *Artemisia* decrease in percent from the bottom to the top of the zone. *Salix* reaches a maximum of 24% in this zone. *Populus* and *Corylus* also attain maximums of 12% and 15%, respectively. Cyperaceae values increase and range from 10 to 50% (calculated outside sum). Frequencies of *Pinus* and *Picea* are similar to those in SL-1. Sole occurrences of *Rumex, Heuchera,* and *Menyanthes* (<1%) are in this zone.

Contacts: The lower boundary is placed where *Artemisia* decreases from 58% to 40% and *Betula* abrubtly increases from 1 to 15%. The upper boundary is placed where *Betula* decreases from 35 to 28% while *Picea* increases from 4 to 30%, at 330.5 cm.

Radiocarbon Age: Ages for SL-2 were not directly determined, but estimated by correlation with zone ML-2 of nearby Mitchell Lake as 16,100 to 11,400 years B.P.

Influx: Pollen concentration values range from 18,228 to 35,715 and average 25,735 grains cm^{-3} $year^{-1}$.

Remarks: While percent values for *Artemisia* and Gramineae show a significant decrease, concentration values for these taxa hold steady. In the top portion of the zone, carbonate percent decreases to zero as organic matter content begins to increase.

Comparisons: Pollen assemblage zone ML-2, Mitchell Lake.

Pollen Zone SL-3 (*Picea* Zone), 330.5 - 295 cm

Description: Zone SL-3 is characterized by increased percentages of *Picea* and Cyperaceae. *Picea* reaches a maximum of 68% in this zone. Cyperaceae increases enormously to a maximum of 95% calculated outside the sum. *Alnus* occurs consistently in this zone ranging from 3% to a maximum of 9%. *Salix, Populus,* Gramineae, and *Artemisia* decrease to minimum values of 1 to 3%. *Pinus* ranges from 15 to 31%. *Valeriana* (<1%) is restricted to this zone.

Contacts: The lower boundary is placed where *Picea* increases from 4 to 30%. The upper boundary is placed where *Picea* decreases from 30 to 20% and *Pinus* increases from 19 to 45%, at 295 cm.

Subzones: The following subzones are delimited:

> SL-3A, 330.5-320.5 cm. In this section of the zone *Betula* pollen decreases to very low values (2 to 8%).
>
> SL-3B, 320.5-295 cm. Subzone SL-3B is dominated by *Betula* pollen, which rises in a second peak with values from 24 to 52%. *Larix, Alnus, Populus, Corylus,* Chenopodiaceae-*Amaranthus, Sarcobatus,* and *Thalictrum* values are higher in this subzone than in Subzone SL-3A. Crucifereae, *Astragalus, Epilobium, Galium,* and *Valeriana* all occur in SL-3B and not in SL-3A.

Radiocarbon Age: Ages for SL-3 were not directly determined, but estimated by correlation with Zone ML-3 of nearby Mitchell Lake as 11,400 to 8,000 years B.P.

Influx: Pollen concentration values range from 128,287 to 931,769 and average 470,608 grains cm^{-3} $year^{-1}$.

Remarks: Both percentages of total arboreal pollen and total pollen concentration increase abrubtly at the beginning of this zone. Although the *Betula* peak in subzone SL-3B compares with the earlier peak in zone SL-2 in percent, the pollen concentration values of the second peak are much higher. Carbonate percent is zero for most of this zone.

Comparisons: Pollen assemblage zone ML-3 at Mitchell Lake.

Pollen Zone SL-4 (*Pinus* Zone), 295 - 280 cm

Description: Zone SL-4 is characterized by an abrupt increase in *Pinus*, which with values of 62 to 65% is the most abundant pollen type. *Picea* (13 to 15%), *Betula* (7 to 11%), *Populus* (<1%), and *Corylus* (<1%), have all decreased from the preceding zone. Liguliflorae and *Trifolium*, with sole occurrences of <1% are confined to this zone.

Contacts: The lower boundary is placed where *Pinus* increases abrubtly from 19 to 45%, at 280 cm. The upper boundary is placed at the bottom of the Mazama ash layer although Zone SL-4 most likely extends upward throughout the nonanalyzed section of the core.

Radiocarbon Age: Ages for SL-4 were not directly determined, but estimated by correlation with Zone ML-4 of nearby Mitchell Lake as 8,000 to 6,800 years B.P.

Influx: Pollen concentration values range from 152,317 to 280,186 and average 216,252 grains cm^{-2} year^{-1}.

4.3 Nordegg Pond

4.3.a Site Description

Nordegg Pond ($116^{o}06'$W, $52^{o}29'$N), (informal name) is in the Brazeau Range area of the Rocky Mountain Foothills of western Alberta at approximately 1230 m elevation and 1.5 km NW of the town of Nordegg, Alberta (Fig. 4.15), which is approximately 80 km northwest of Mitchell and Strubel Lakes. Nordegg Pond is a small, approximately 135 m diameter marly pond with an area of about 1.8 hectares. It is surrounded by bog with no inflowing streams. The pond basin is shallow, with a maximum depth of 1 m (Fig. 4.16). Underlying bedrock is made up of Paleozoic and younger Mesozoic rock of the Blairmore Formation. The surficial deposits of the area are unmapped, although just off Boydell's (1978) map.

The climate of the area is characterised as cool continental-temperate, with long cold winters and short cool summers. Climatic normals (Environment Canada 1982:155) are available from the Nordegg Ranger Station approximately 1 km from Nordegg Pond. For the period 1951-1980, the mean January temperature was -14.0^{o}C, while the extreme temperatures ranged from -47.2^{o}C to 16.7^{o}C. The mean July temperature was 12.6^{o}C, with temperature extremes ranging from 31.1^{o}C to -6.7^{o}C. The mean annual precipitation was 555 mm. Higher precipitation occurs during the summer months (Fig. 4.17). The area is usually dominated by Arctic air in winter and spring, whereas the summer is primarily influenced by Maritime air masses (Alberta Weather Centre 1989).

Nordegg Pond, considered to be within the Upper Foothills section of the boreal forest according to Rowe (1972), and the subalpine forest according to North (1976), can be considered as within the transitional area between the western boreal and subalpine forests. In the immediate vicinity

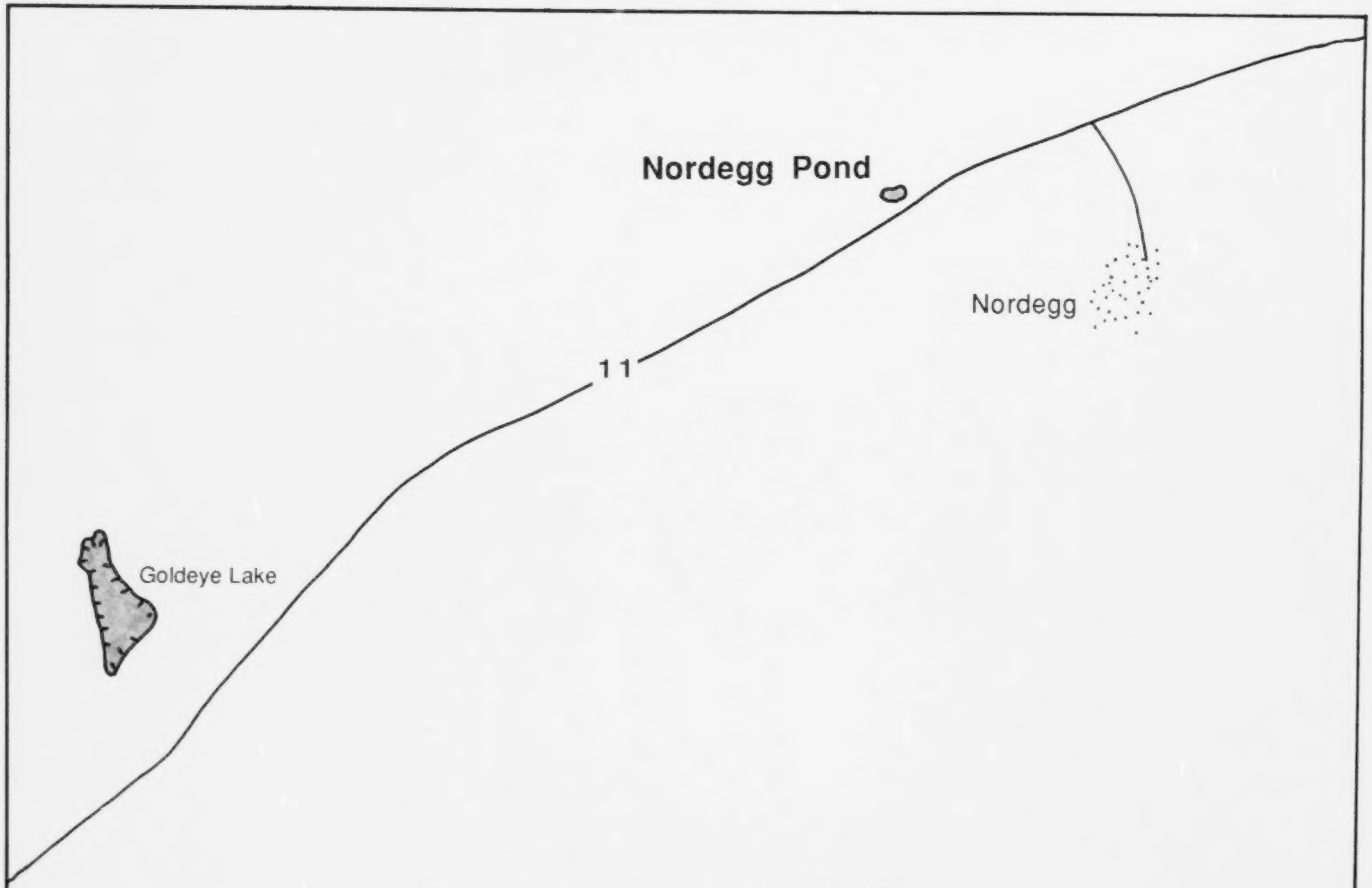

Nordegg Pond
Nordegg
11
Goldeye Lake

Figure 4.15 Nordegg Area Location Map

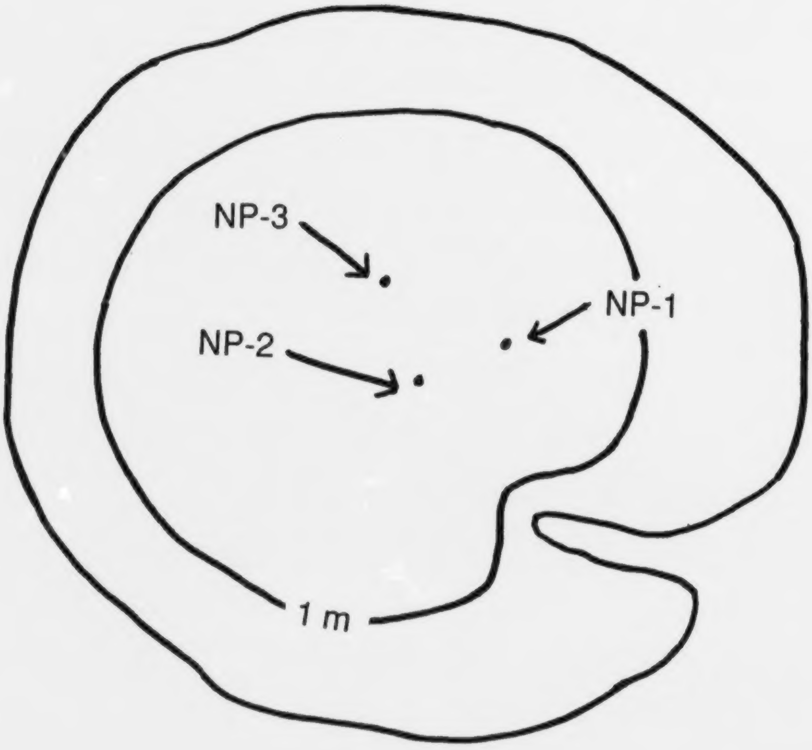
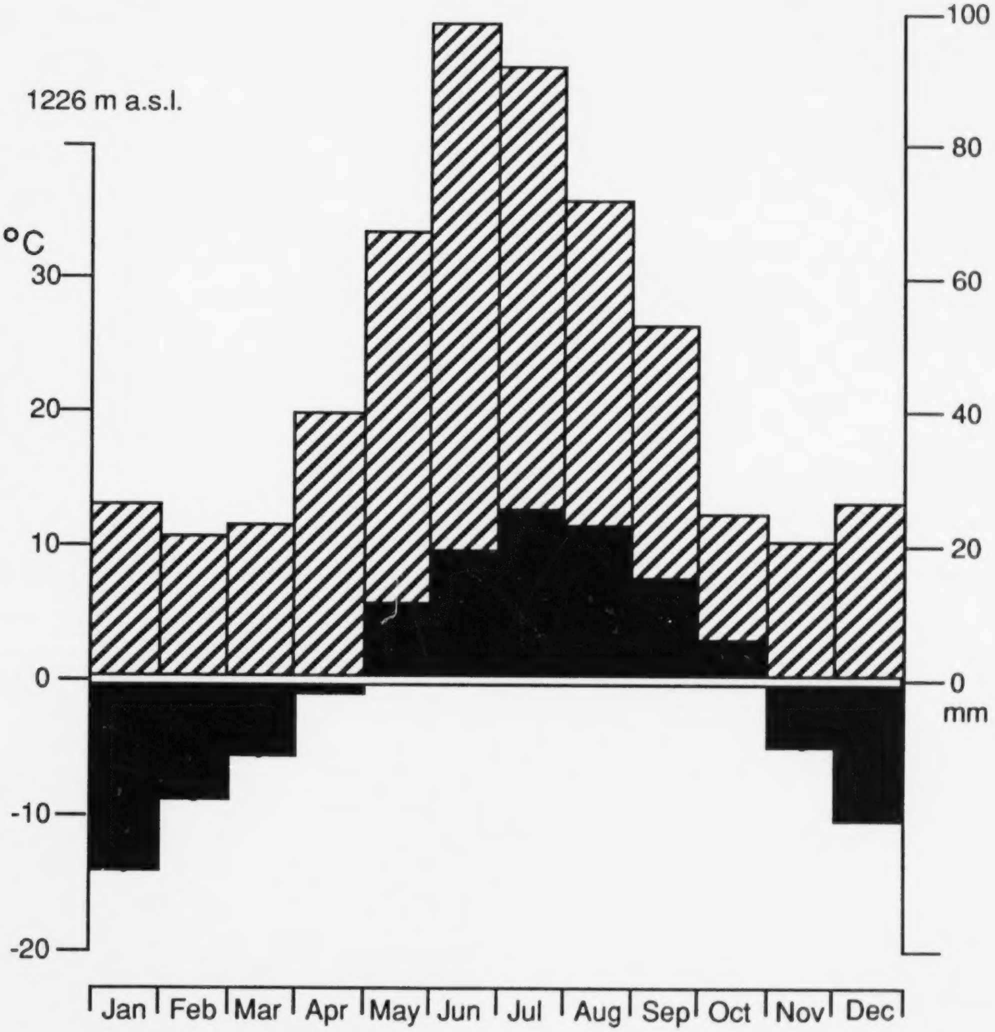

NP-3
NP-1
NP-2
1 m

Figure 4.16 Nordegg Pond Bathometry and Coring Sites

Figure 4.17. Climatic Normals, 1951-1980, Nordegg Ranger Station



■ Mean Monthly Temperature

▨ Mean Monthly Precipitation

Plotted from values reported by Environment Canada (1982) of the pond the dominant tree species are black spruce (*Picea mariana*), larch (*Larix laricina*), and white spruce (*Picea glauca*). Pine (*Pinus contorta*) is found nearby. There is also abundant willow (*Salix*) and dwarf birch (*Betula glandulosa*) surrounding the pond with a diverse selection of herbs and aquatic plants.

4.3.b Sediment description

The Nordegg Pond sediment core is predominantly composed of marl from 0 to 357 cm and clay from 357 to 405 cm (Table 4.5). The maximum values for carbonate content correspond to the marl section of the core (Fig. 4.18). Moisture content appears to increase with the establishment of marl and then remains steady although the low moisture content at the base of the core could be a reflection of compacted sediments (Adams and Duthie 1976:24).

4.3.c Radiocarbon Dating and Core Chronology

A chronology for Nordegg Pond was established using radiocarbon dates (Table 4.6) and the accepted ages of Mt. St. Helen's Y (3400 B.P.), and Mazama (6800 B.P.) tephras (Mullineaux 1974; Bacon 1983). While other methods, e.g., linear regression and piecewise polynomial approximation yielded near identical trends in date/depth relationships, it is not clear that the smoothing of data is desirable or useful. Therefore linear interpolation between dates was used to plot radiocarbon age versus sediment depth (Fig. 4.19).

4.3.d Discussion of dates

The Nordegg Pond radiocarbon dates are assumed to be correct as no dating reversals occurred and the chronology correlates well with expected dates for similar events in the region. The 8925+/-145 date is reliable, being on a large well preserved *Picea* twig. The 10,500+/-140 date on *Potamogeton*

Table 4.5. Lithologic Units of Nordegg Pond[a]

Depth (cm)	Description and Color[b]	Lower Contact	Remarks
0-357	Marl, 10YR 6/2	Gradational over 20 cm.	Firm. Distinct bands[c] of 10YR 5/2, 10YR 5/3, 10YR 6/3. Tephra unit at: 242-248 cm.
357-405	Clay, 10YR 4/1, 10YR 3/1		Firm. Sand lens at: 384-386, 398-399, 404-405 cm.

[a] Core NP-1 used for sediment description.

[b] Munsell color notation (GSA Rock Color Chart, 1975)

[c] After Mehringer et al. (1977), bands refer primarily to difference in color whereas laminations differ primarily in texture.

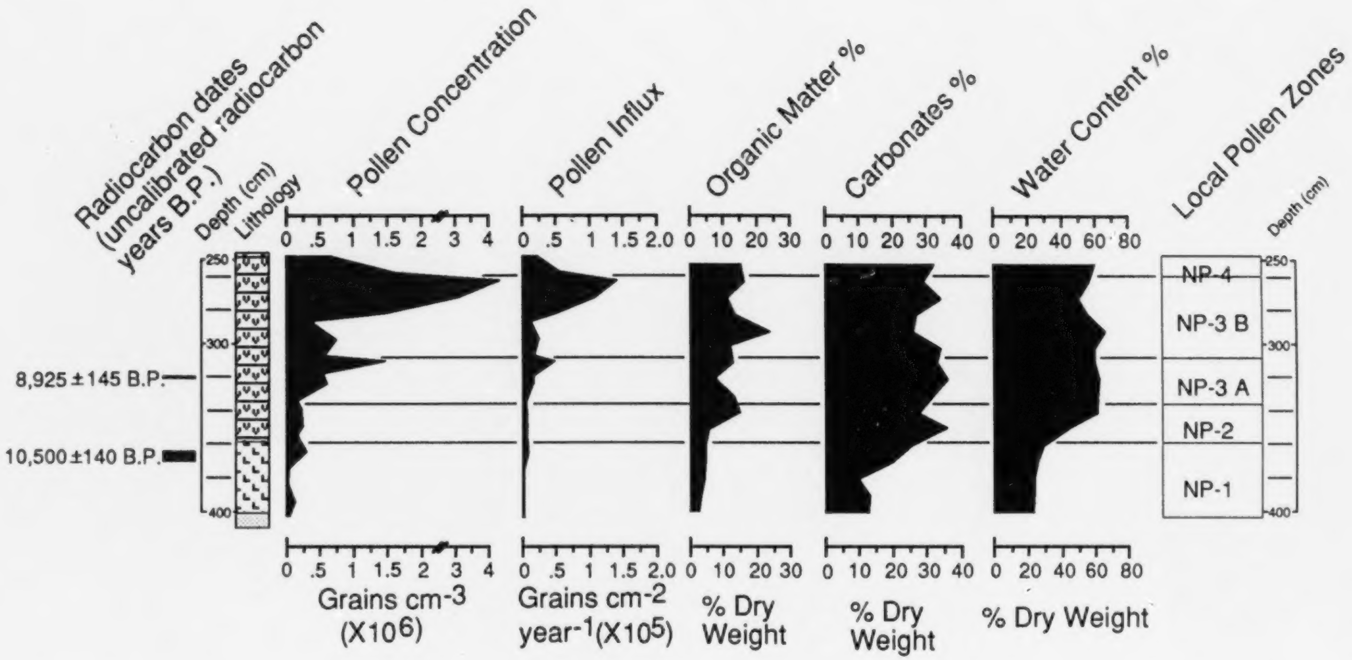


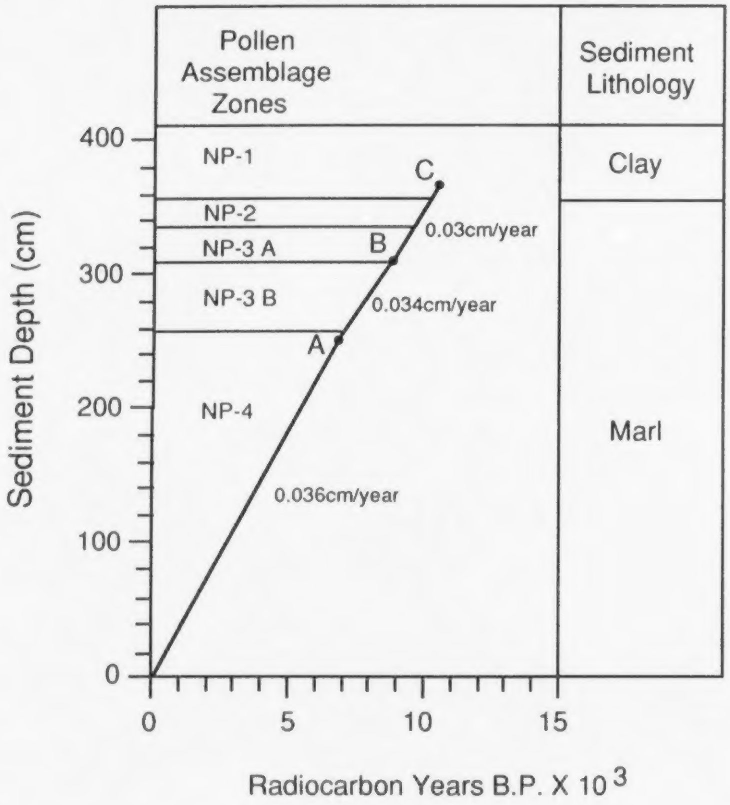
Figure 4.18. Sediment stratigraphy at Nordegg Pond in relation to local pollen zones, total pollen concentration and pollen-influx curves,percentage loss-on-ignition curves (organic matter and carbonates), and percent water content.

Table 4.6. Nordegg Pond Radiocarbon Dates

Depth(cm)[a]	Material	Age (yr B.P.)[b]	Lab No.[c]
320	*Picea* twigs	8,925 +/- 145	Beta-252261/ETH-3740
365-370[d]	*Potomogeton* seeds	10,500 +/- 140	Beta-251481/ETH-3736

a, Depth below mud surface on composite core.
b, Uncorrected radiocarbon years.
c, Beta/ETH, Beta Analytic, University Branch, Florida/Eidgenossisdie Technische Hochschule, Zurich.
d, Seeds collected from correlative segments of 5cm each from three duplicate cores.

Figure 4.19. Nordegg Pond Sedimentation. A, Mazama; B, Beta-25226/ETH-3740; C, Beta-251481/ETH-3736



seeds is possibly equivocal, as *Potamogeton* is both a submergent and floating aquatic, and may incorporate dissolved carbonates and any available old carbon, into its structure. It is possible, however, that such contamination is less of a problem in a pond such as Nordegg where carbonate is a major component of the sediment (Turner et al. 1983:614).

4.3.e Pollen Zone Descriptions

Pollen data are plotted as percent (Fig. 4.20) and influx values (Fig. 4.21) within zone boundaries determined with the aid of the SPLITINF, SPLITLSQ, and CONSLINK programs (Fig. 4.22). Although pollen bearing sediment extends to 403 cm, samples below 394 cm had sums less than 200 grains and are not shown on the diagrams except to indicate presence or absence.

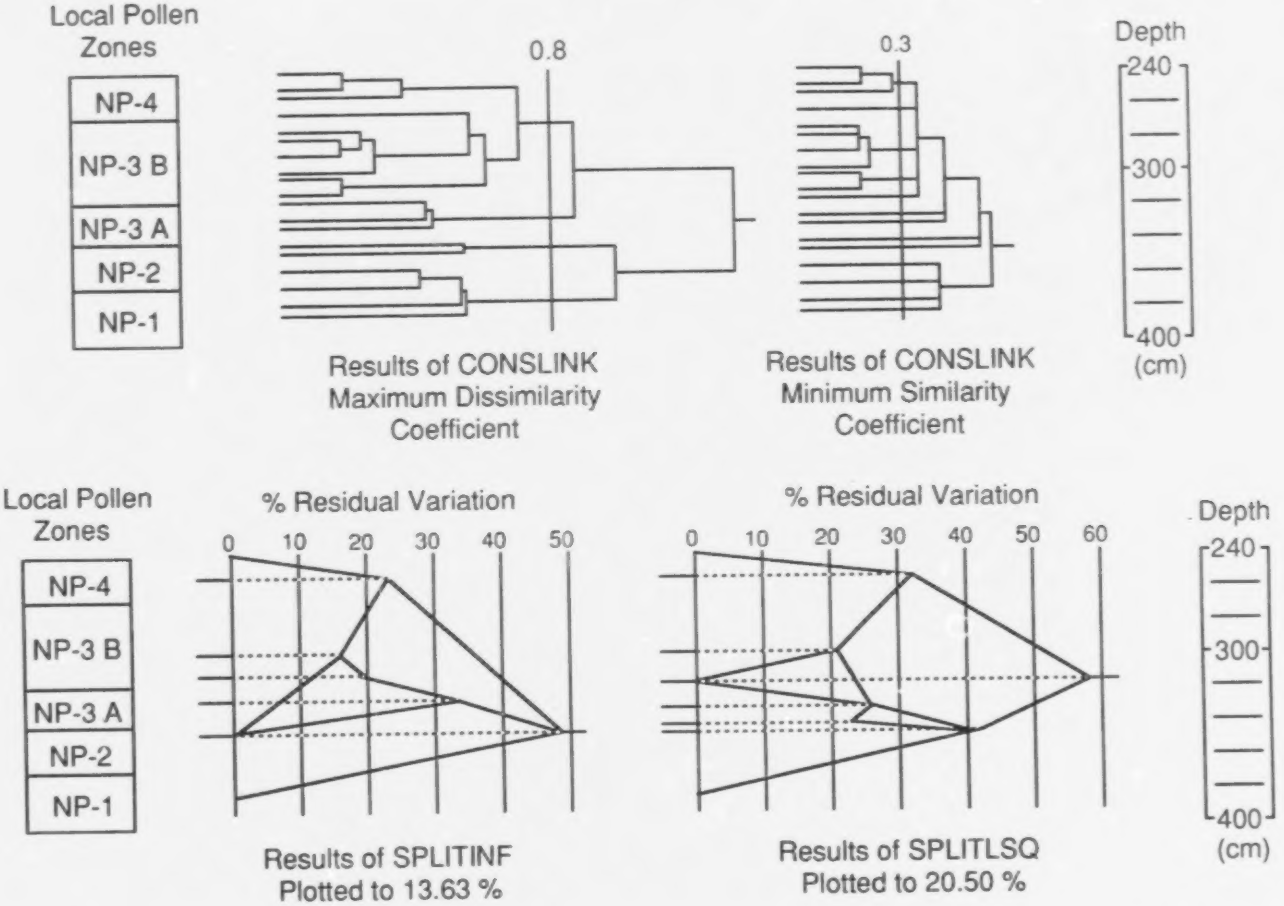
Pollen Zone NP-1 (*Artemisia*-Gramineae Zone), 394 - 359 cm

Description: Zone NP-1 is dominated by *Artemisia* pollen with maximum values of 49 to 75%. Gramineae pollen is also at a maximum with values of 5 to 10%. *Salix* values range from <1 to 5%. Cyperaceae is at a maximum, ranging from 2 to 7%. *Pinus* values range from <1 to 35%. *Picea, Betula, Alnus, Populus, Shepherdia canadensis,* Tubuliflorae high spine, and Rosaceae occur consistently at low (<1 to 2%) values. Chenopodiaceae-*Amaranthus* values range from 1 to 3%. *Gentianella, Galium, Valeriana, Phacelia,* and Leguminosae are restricted to this zone.

Contacts: The lower boundary is the base of pollen-bearing sediment. The upper boundary is placed where *Artemisia* decreases to 25%, at 359 cm.

Radiocarbon Age: The age of this zone is estimated at greater than 12,000 to 10,200 years B.P.

Figure 4.22. Numerical Zonation of Nordegg Pond as calculated from percentages of *Pinus, Picea, Betula, Alnus, Salix, Artemisia,* and Gramineae.



Results of CONSLINK Maximum Dissimilarity Coefficient

Results of CONSLINK Minimum Similarity Coefficient

Results of SPLITINF Plotted to 13.63 %

Results of SPLITLSQ Plotted to 20.50 %

Influx: Zone values range from 887 to 9237 and average 3750 grains cm^{-2} $year^{-1}$.

Remarks: Very high (1000-4000 grains cm^{-2} yr^{-1}) pollen influx values for *Artemisia* occur in this zone. Carbonate percent increases from 10 to 30%.

Pollen Zone NP-2 (*Betula-Salix* Zone), 359 - 336.5 cm

Description: Zone NP-2 is dominated by *Betula* pollen with maximum values of 35 to 84%. *Salix* pollen reaches a maximum of 12%. Gramineae, *Artemisia* and Cyperaceae occur with values of 1 to 5%. *Corylus* reaches a maximum of 3%. *Populus*, and Tubuliflorae high spine occur consistently with values of <1 to 2%. *Pinus* values range from 1 to 43%, while *Picea* ranges from 2 to 10%. *Lathyrus*, with values of <1%, is restricted to this zone.

Contacts: The lower boundary is placed where *Betula* abruptly increases from 1 to 22%. The upper boundary is placed where *Betula* decreases from 35 to 25%, at 336.5 cm.

Radiocarbon Age: The age of this zone is estimated as 10,200 to 9,500 years B.P.

Influx: Zone values range from 5800 to 7595 and average 6602 grains cm^{-2} $year^{-1}$.

Remarks: Carbonate percent remains high (ca. 30%).

Pollen Zone NP-3 (*Picea-Pinus* Zone), 336.5 - 259.5 cm

Description: Zone NP-3 is dominated by arboreal taxa. *Picea* reaches its maximum, ranging from 20 to 59% while *Pinus* values range from 16 to 55%. *Alnus* values range from 2 to 9%, while *Salix* ranges from <1 to 3%. *Abies* and *Populus* occur at low (<1%) values. Tubuliflorae high spine, Chenopodiaceae-*Amaranthus*, Rosaceae and Cyperaceae occur consistently at values of <1 to 2%. *Cornus canadensis, Caltha palustris, Geranium, Epilobium, Typha*, and *Triglochin*, with values of <1%, are confined to this zone.

Contacts: The lower boundary is placed where *Picea* rises from 10 to 22% while *Betula* drops from 35 to 25%. The upper boundary is placed where *Picea* decreases to 30%, at 259.5 cm.

Subzones: The following subzones are delimited:

NP-3A, 336.5-308.5 cm. In this section of the zone *Betula* pollen decreases to low values of 5 to 12%, while *Alnus* reaches its maximum of 9%. *Cornus canadensis, Geranium*, and *Plantago* occur in this subzone but are absent from NP-3B.

NP-3B, 308.5-259.5 cm. *Betula* pollen displays a second peak, rising from 13 to 28% before decreasing to 2% at the top of the zone. *Juniperus, Caltha palustris, Epilobium*, and *Typha* all occur in this subzone but are absent from NP-3A.

Radiocarbon Age: The age for this zone is estimated at 9,500 to 7,200 years

B.P. with the subzone NP-3A/NP-3B boundary dated at 8,100 years B.P.

Influx: Zone values range from 4995 to 141,927 and average 44,767 grains cm^{-2} $year^{-1}$.

Remarks: Although the second *Betula* pollen peak in subzone NP-3B is smaller in percent than the first peak in zone NP-2, the pollen influx values of the second peak are significantly higher than the first. Total pollen influx values increase abruptly in the middle of subzone NP-3B. Carbonate percent remains high.

Pollen Zone NP-4 (*Pinus* Zone), 259.5 - 247 cm

Description: Zone NP-4 is characterized by an increase in *Pinus* pollen, with values of 67 to 76%. *Picea* pollen has declined, ranging from 16 to 22%. *Betula* pollen ranges from 1 to 2% with *Alnus* at 3 to 4%. Most herbaceous taxa that occurred earlier in the core are absent from this zone.

Contacts: The lower boundary is placed where *Pinus* pollen increases from 55 to 76% while *Picea* pollen decreases from 40 to 16%. The upper boundary is placed at the bottom of the Mazama ash layer, although presumably the zone extends upward throughout the non-analyzed section of the core.

Radiocarbon Age: The age of this zone is estimated at 6,800 to 7,200 years B.P.

Influx: Zone values range from 23,224 to 55,129 and average 39,176 grains cm^{-2} $year^{-1}$.

Remarks: Though insignificant in percent, *Abies* and *Larix* pollen influx values are at a maximum in this zone. Carbonate percent remains high.

5. Paleoenvironmental Interpretations

5.1 Introduction

5.1.a Definitions

There are many inconsistencies in the application of such terms as full-glacial and late-glacial. Part of the problem is that although an approximate global synchroneity is often assumed, the post-glacial, for example, may have occurred at different times in different areas. Thus while global trends should be taken into consideration, time periods should be defined on the basis of local and regional circumstances. Following Ritchie's (1987) guidelines, and the constraints of my data, I define the following approximate time periods for use in the following discussion:

a) full-glacial (ca. >18,000 to 16,000 yr B.P.), defined as the period and events associated with maximum extent of glacial ice;

b) late-glacial (ca. 16,000 to 12,000 yr B.P.), defined as the period and events associated with transitional conditions, when "glaciers were still widespread and, while occasionally expanding, were in general receding" (Ritchie 1987:6);

c) post-glacial (ca. 12,000 to 10,000 yr B.P.), defined as the period and events following the local disappearance of glacial ice, or the end of a glacial climate.

Arguments could be made for alternative dates. In particular several authors argue that the 10,000 B.P. date for the onset of Holocene times should be pushed back to 13,700 B.P. on the basis of worldwide indicators of extreme climatic change commencing at this time. Obviously part of the problem is semantic; i.e., if the post-glacial is after the glacial, isn't it simply the earliest part of the Holocene? Whether or not the post-glacial climate began globally ca. 14,000 years ago, the differing lag times of various responses to the change cause temporal and spatial variability in its expression. In any case my data lack the resolution to distinguish, for example, a 14,000 to 12,000 yr B.P. period. For these and other reasons, including simple ease of reference, I use the periods described above. Furthermore, although the pollen percentage and influx data presented extend up to approximately 6800 B.P., the paleoenvironmental reconstruction presented here does not extend past 10,000 B.P., as the vegetation and environment of the Holocene are irrelevant to the objectives of this study.

5.1.b Analytical Approach

The following vegetational interpretation is based on qualitative consideration of indicator species, modern pollen influx and percentages, and pollen ratios, used as interpretative analogues. Quantitative methods, for example squared chord-distance measures (Anderson et al. 1989), are not applicable here, primarily because

1) there isn't a large enough data base of northern Plains sites to use for comparison, and

2) simple percentage comparisons do not reflect differences between steppe and grassland vegetation, as will be discussed below.

Additionally, while Anderson et al. (1989) feel that squared chord-distance measures can identify modern analogues for full-glacial (defined by them as 18,000 to 15,000 B.P.) vegetation in northwestern North America, they admit the method is unable to identify modern analogues for largely nonarboreal assemblages. They further conclude that the method is wholly ineffective for pollen spectra from the late-glacial (defined by them as 14,000 to 10,000 B.P.), effectively demonstrating that "late-glacial vegetation lacks similarity in the present landscape" (Anderson et al.

1989:595). Consequently, it is concluded that such quantitative measures cannot contribute to the interpretation of the largely nonarboreal assemblages presented in this study.

5.2 Problems in Herb Zone Interpretation

Full- and late-glacial pollen assemblage zones dominated by various combinations of *Artemisia*, Gramineae, and Cyperaceae have been reported from many sites over northwestern North America, from the northern Great Plains to Alaska. Such zones, commonly known as "herb zones," are problematic in interpretation. One indication of this is the varied and often contradictory reconstructions that are based on essentially similar pollen assemblages. Proposed vegetation ranges from discontinuous fellfield (Cwynar 1982), tundra (Birks 1976), or continuous steppe-tundra or grassland (Guthrie 1966; Matthews 1974), to a steppe-tundra mosaic (Schweger and Habgood 1976; Schweger 1982). Before the herb assemblages in the present study can be interpreted, the difficulties inherent in herb zone vegetational and environmental reconstruction must be considered.

In addition to prominent *Artemisia*, Gramineae, and Cyperaceae, and a correspondingly low level of arboreal pollen, a typical herb zone pollen assemblage commonly has Chenopodiaceae-*Amaranthus*, Compositae, and other minor taxa suggestive of disturbance or exposed mineral soil. Pollen influx is generally less than 100 g cm^{-2} yr^{-1}, with low organic matter content of the highly minerogenic sediments (Cwynar 1982; Anderson et al. 1988). One of the key difficulties in interpretation is that such an assemblage shows affinities to both modern grassland and/or steppe (Lichti-Federovich and Ritchie 1968; Hansen and Wright 1987; Grichuk 1984) and tundra vegetation (Birks et al. 1975; Cwynar 1982; Birks

1986), with no definitive correlations to either type of vegetational community.

The first widely accepted scenario for late Pleistocene vegetation in North America was that of an extensive, productive grassland (Guthrie 1966; 1968). This was described variously as grassland (Colinvaux 1964), continuous arctic steppe (Matthews 1976), and steppe-tundra (Young 1976). It was felt that the high amounts of *Artemisia* and Gramineae in the pollen assemblage zones, a presumed continental climate in glacial times caused by the emergence of the Beringian land mass and changing atmospheric patterns, and the requirements of an abundant largely herbivorous fauna, indicated a vegetation typical of grassland rather than tundra.

Guthrie (1966) was apparently the first to use the term steppe-tundra in an English language publication to describe this vegetation, borrowing the term from Russian researchers (Hibbert 1982). In Russia, steppe-tundra refers to an association of predominantly herbaceous plants with co-dominance of steppe and arcto-alpine species (Walter 1979). Problems arose in North America when the term steppe-tundra was applied to a reconstruction of continuous, highly productive grasslands whose main arctic component was low temperatures, not species composition. This usage, by differing from the original intent of the term, resulted in much misunderstanding and debate over the steppe-tundra concept. There are significant differences between steppes, grasslands, and tundras; although the general way these terms are used often obscures them.

Besides problems of semantics, there were other criticisms of the grassland/steppe-tundra concept. Schweger and Habgood (1976) argued that the large, diverse vertebrate assemblages invoked as requiring a productive grassland biome did not exist in reality; but were more likely to be mixed assemblages from various periods of differing climatic conditions combined by fluvial activity and less than rigorous excavation techniques. They were also the first to propose a mosaic model of vegetation, in which the environment was envisioned as a mosaic of local and regional combinations of steppe, grassland, and tundra vegetation dependent on variables of slope, aspect, and available moisture.

Cwynar and Ritchie (1980) also rejected the traditional grassland concept and argued for a mosaic of tundra types. They based their argument on the fact that low pollen influx in the herb zone indicated a sparse vegetation, not an abundant grassland; and secondly, that the assemblage had affinities not to cold temperate grasslands but to arctic-alpine vegetation for which analogues could be found locally. They concluded that the herb zone represented a "sparse, discontinuous vegetation of herbaceous tundra on upland sites and local sedge-grass meadows on lowlands" (1980:1377).[1]

Most workers proceeded to incorporate the mosaic concept (cf. Hopkins et al. 1982; Barnosky et al. 1987b) and rejected the concept of a continuous productive grassland. Although presumed steppe (Barnosky 1985), grassland (Vance 1986b; MacDonald 1989), or tundra (Ritchie 1984; Anderson et al. 1988) affinities of various herb zone assemblages are often indicated, they are usually referred to as a "sparse herbaceous assemblage"; perhaps in an attempt to avoid the familiar terms tundra, steppe, and grassland that can conjure up a reconstruction that is not implied.

---

[1] Guthrie (1985; 1990a) has recently revised his conception of Pleistocene vegetation, proposing the term 'mammoth steppe' to indicate a predominance of short, widely-spaced vegetation that he emphasizes cannot be understood without consideration of the fauna it supports.

In light of this admittedly brief discourse on the development of herb zone interpretation it may be asked how this will aid in the interpretation of the herb zone assemblages in this study. First, the references mentioned earlier that advocate a mosaic approach to the vegetation, while also indicating affinities of the herb assemblage to specific vegetation formations, show a clear pattern. It is not coincidental that those references that refer to tundra affinities occur in the north (cf. Anderson et al. 1988), while those references that refer to steppe or grassland affinities occur in the southern region of the area covered by nonarboreal pollen assemblages in glacial times (cf. Barnosky 1985; MacDonald 1989). Birks (1973:165) has stated that problems in interpretation are caused when vegetational analogues are sought elsewhere, "thereby introducing a transfer in space as well as in time." Perhaps there has been too much emphasis on the Arctic and Beringia. Investigators in areas outside the immediate sphere of influence of Beringia might do well to look closer to home for their analogues. Southeastern Washington is not the Arctic; neither is west central Alberta (although I certainly thought so my first winter here!).

Despite of the strong resistance to steppe and grassland as viable analogues for full-glacial and late-glacial vegetation, it is time to reevaluate these terms. First, the terms themselves are often misunderstood; they are not equivalent terms but refer to different types of vegetational assemblages with differing moisture budgets. Secondly, just as there is great variability between and within forest types, there is variability within steppes and grasslands.

Unfortunately, due largely to the semantic problems surrounding the term "steppe-tundra," steppe and grassland have been taken by many to be equivalent, interchangeable terms. It is common in North America to use grassland as an all-inclusive term. Barbour et al. (1980:522), for example, state "we will use grassland as a general term applicable to prairie, steppe, and all intermediates." In this sense steppe is seen as a type of, or subset of grasslands. Such an approach emphasizes similarities between steppes and grasslands while minimizing differences. This conception has contributed to the present situation where most investigators consider only two options, 1) tundra, or 2) grassland/steppe, when analyzing their herb zones, and then usually in very broad terms. This either/or approach is only partly ameliorated by the mosaic approach. There is still a distinct lack of modern analogues for cold steppe or tundra assemblages. What the mosaic approach has done primarily is to change the scale of the problem. We are no longer simply looking for entire equivalent biomes, but for smaller local and regional analogues.

Cwynar (1982) illustrates how a finer grained approach to variability within the tundra environment and emphasis on local analogues assisted in paleoenvironmental interpretation of the record at Hanging Lake in the Yukon. Barnosky (1985) also makes use of local analogues in her analyses at Carp Lake in the Columbia Basin of Washington. The Carp Lake record "indicates a dominance of steppe vegetation throughout the late Pleistocene and implies that droughty soils at low altitudes limited trees as they do today" (Barnosky 1985:114). This work utilized an often overlooked factor, that aridity can be as important a limiting factor on the growth of trees as cold. This suggested a closer look at the semiarid steppes and intermountain grassland extending from Washington, Oregon, Idaho, through Utah, Wyoming and southwest Montana.

The most typical confusion of steppe and grassland equates what has been defined as the "prairie" of North America (Barbour et al. 1980:522) with the steppes of Eurasia. Setting aside Russian definitions for the moment, there is room for significant misunderstanding within North America. The term prairie should be restricted to "a grassland dominated by tall, sod-forming grasses with 100% cover" (Barbour et al. 1980:522). Prairie and grassland should not be considered equivalent terms; although all prairies are grasslands, all grasslands are not prairies. Envisioning a rolling tall grass prairie whenever one hears the term grassland can result in misinterpretations.

The present-day semiarid steppes and intermountain grasslands of the northwestern United States have been referred to as outlying grasslands, intermountain grasslands, steppes, shrub steppes, desert scrub, and semi-desert (Barbour et al. 1980; Bright 1966; McAndrews and Wright 1969; Walter 1979). Several of the terms are used concurrently by a single author, albeit while discussing different vegetation zones. This is not ecological schizophrenia. Large areas of the northwest are covered by semiarid treeless vegetation that varies in composition on different scales due to variables in rainfall and soil patterns (Heusser 1983).

The distribution of grassland and steppe vegetation is controlled mainly by available moisture (Spaulding et al. 1983: Guthrie 1990a). These vegetation subtypes can be placed on a continuum of variability relating largely to moisture stress, which in North America increases from east to west. Starting with the classic prairie grassland of the eastern Great Plains, with 40 to 60 cm annual precipitation as a baseline of maximum available moisture, vegetation ranges from intermountain grassland, and intermountain steppe, to shrub steppe and the desert scrub of the Great

Basin "cold" or semi-desert.

Precipitation in the intermountain grassland averages 25 to 45 cm annually, with 15 to 30 cm in the shrub steppe, and 5 to 25 cm in the desert scrub (Barbour et al. 1980; McAndrews and Wright 1969). Along with low precipitation, grasslands and steppes are generally characterized by high evaporation. All grasslands, steppes, and deserts have a precipitation to evaporation index (P/E) less than one. Church (1976) notes that deserts are generally characterized by an unavailability of moisture. In warm deserts this moisture deficiency is caused by a combination of low precipitation and high evaporation. Deserts in arctic regions also have low precipitation (10 to 50 cm), but low evaporation, resulting in a P/E ratio greater than one. The aridity in arctic areas comes not from high evaporation but because the little precipitation that does fall may remain unavailable on the surface as ice or snow. It appears that "cold continental steppes may share features of both desert types" (Church 1976:37).

Amount of vegetation cover also decreases with increased moisture stress, as "the drier the region, the further apart the plants grow" (Walter 1979:103). From a high of 100% ground cover in the eastern prairie, ground cover decreases to 15 to 40% in the desert scrub. Another clear pattern is changes in the proportions of various taxa. Although these vegetation types are largely similar in terms of particular taxa present, they differ in degrees of relative abundance. With increasing aridity, grasses decrease and sages increase. Other taxa show similar patterns, e.g., *Sarcobatus* and other Chenopodiaceae increase with increasing aridity.

Unlike the clear tripartite division of the classic prairie into tallgrass, mixed, and short grass divisions associated with decreasing moisture on an east-west transect, most change in the semiarid regions is nonlinear. This situation can be best understood by envisioning the area as one large ecotone where grases and sages,

> occur side by side under the same general climatic conditions and are in a state of keen competition. Which of the two types is successful depends on the microclimatic conditions resulting from local relief or soil texture, so that there is a diffuse mixture of the two kinds of vegetation or a mosaic like pattern of the two (Walter 1979:5).

To summarize, although steppes and grasslands are often considered comparable vegetations, they can be clearly distinguished. While both steppes and grasslands are characterized by aridity, steppes are drier than grasslands. This difference is reflected by other contrasting characteristics of steppe and grassland vegetation (Table 5.1). Once the distinction between modern grassland and steppe vegetation is clear, the next concern is to see if these differences are reflected in the modern pollen rain. If pollen spectra are examined superficially there is no clear difference between the two. Like the tundra spectra against which they are usually compared, steppe and grassland pollen spectra both have high nonarboreal pollen, and low arboreal pollen, in addition to the ubiquitous presence of *Artemisia*, Gramineae, Cyperaceae, and Chenopodiaceae-*Amaranthus*.

Although it has been suggested that pollen analysis generally lacks the resolving power necessary to distinguish tundra from grassland or steppe (Vance 1986a), grassland and steppe spectra are often compared to tundra spectra in an attempt to interpret herb zone pollen assemblages. The distinction generally depends on the presence of tundra indicator species and how the presence of *Artemisia* is interpreted (Barnosky et al. 1987b). Usually "high" *Artemisia*, which in general practice means "high in relation to expected arctic values," is said to suggest grassland

Table 5.1 Characteristics of Steppes and Grasslands

CHARACTERISTIC	STEPPES	GRASSLAND
Precipitation	5-30 cm	25-60 cm
Humidity Province	Semiarid	Subhumid
Dominant Vegetation	Co-dominance of short bunchgrasses and shrubs	Graminoids (grasses, sedges, rushes)

Bright (1966), McAndrews and Wright (1969), Walter (1979), Barbour et al. (1980)

affinities, while arctic or alpine species indicate tundra. Grassland indicators are often seen as troublesome or equivocal and are often ignored or explained away as due to long distance transport.

Accepting the quantitatively imprecise designation of "high" *Artemisia* as an indication of grassland or steppe has further obscured the differences between them. The term "high" *Artemisia*, frequently encountered in descriptions of modern and fossil arctic pollen spectra, generally means higher than 5% and seldom higher than 15 to 20% (cf. Cwynar 1982). But both modern grassland and steppe pollen spectra show *Artemisia* values significantly higher than 5%.

A closer inspection of modern steppe and grassland pollen spectra reveals two patterns. One is that *Artemisia* values are generally higher in steppes than in grasslands. The other is that the ratio of *Artemisia* to Gramineae in a grassland is less than one; in a steppe it is greater than one (Table 5.2). Although only the studies cited in Table 5.2 had data available for quantitative analyses, every applicable study examined supports this relationship between *Artemisia* and Gramineae. Both the higher amounts of *Artemisia* pollen and its increase relative to Gramineae support observations (cf. Bright 1966) that steppe vegetation, unlike grassland, is not dominated by grasses. Although high *Artemisia*:Gramineae ratios have often been interpreted to indicate low effective moisture and increased aridity (Mehringer 1985; Barnosky 1989), the association of *Artemisia*:Gramineae ratios greater than one with steppe vegetation, and less than one with grasslands, may have been overlooked. This is not surprising considering the usual lumping of grassland and steppe vegetation types into a larger vegetation complex characterized primarily by its lack of arboreal vegetation.

Table 5.2. *Artemisia*:Gramineae Ratios From Steppe and Grassland Vegetation

Artemisia/ Gramineae Ratio[a]	G	S	COMMENTS AND NOTES
.3	X		Manitoba (Lichti-Federovich & Ritchie 1965)
.4	X		North Dakota (Hansen & Wright 1987)
.4	X		"prairie" (McAndrews 1966, 1967 cited in Birks 1980)
.4 -.8	X		Range in ratio depends on whether heavily grazed pastures high in *Artemisia* (40-60%) are included in calculations. South Dakota (McAndrews and Wright 1969)
2.3		X	"semi arid open grassland"[b], Okanagan Valley, B.C. (Alley 1976)
3.9		X	*Artemisia* Steppe, Gardiners Hole & Cub Creek Pond, NE Wyoming (Baker 1983)
7.7		X	*Artemisia* steppe around Swan Lake, Idaho (Bright 1966)
10.0		X	Shrub steppe in Green River and Wind River basins, Wyoming (McAndrews & Wright 1969)

G=Grassland, S=Steppe

[a] Ratios are my calculations from average percentages of *Artemisia* and Gramineae from surface samples and modern pollen rain analyses in non-forested areas.

[b] Although Alley characterizes the vegetation as "semi arid open grassland," it is in fact steppe as described elsewhere in this study.

The relationship between *Artemisia*:Gramineae ratios and vegetation type sheds light on the anomalously "high" *Artemisia* ratios often encountered in fossil pollen assemblages and provides a more quantitative approach to interpreting them. In particular, it is no longer valid to explain away high *Artemisia* as due to long distance transport from lower elevations. Waddington and Wright (1974), for example, felt that the combination of high *Artemisia, Sarcobatus,* and *Picea* in late-glacial pollen spectra from Wyoming meant that *Artemisia* had to have been blown in from high producing *Artemisia tridentata* steppes. Their position was based on the assumption that steppe and boreal vegetation would not likely coexist. Heusser (1983) also felt that high *Artemisia* values (40 to 60%), were caused by long distant transport from lower elevations.

Spaulding et al. (1983), while acknowledging the possible influence of long distance dispersal in alpine sediments with *Artemisia* pollen frequencies less than 20%, questions whether frequencies greater than 40% could be solely the product of upslope winds as many have assumed. He further points out that macrofossil evidence from the Southwestern United States shows mixed associations of steppe species and boreal conifers (e.g., *Artemisia*, and *Atriplex*, with *Pinus*, and *Picea*) during the full glacial, and also that *Artemisia* and assorted montane conifers associate today in the Great Basin. Recent evidence, in fact, has demonstrated that abundant *Artemisia* pollen probably originates locally, indicating not a telescoping of vegetation zones, but rather "a mixture of species . . . which associate only uncommonly under today's climatic conditions" (Solomon and Silkworth 1986:159).

It has been cautioned that errors may arise in "specifying former vegetation on the basis of high *Artemisia* percentages, because the genus has a wide ecological amplitude and because individual species cannot yet be distinguished on the basis of pollen alone" (Matthews 1982:133). However, plant macrofossil records indicate that *Artemisia* was clearly more widespread in the Pleistocene than today (Cole 1990:362). It is possible that certain species and/or genera are particularly well suited to either glacial or non-glacial times. *Artemisia* seems to be such a genus, widespread in glacial times of cold, dry, continental climate and restricted regionally in the comparatively moister non-glacial climates of today.

There is a greater richness of species of *Artemisia* in continental areas; and although some *Artemisia* can grow anywhere, the vast majority of species occur in dry or rocky areas (Cwynar 1982). Wright (1971) suggested that "an edaphic condition favouring the full glacial and late glacial expansion of *Artemisia* may have been provided by the extensive outwash plains that were actively forming at this time" (1971:443). Whatever species are represented, besides aridity, the presence of *Artemisia* indicates low plant cover, well-drained substrates, and possibly deep seasonal thawing (Matthews 1982).

Thus far attempts at speciation of *Artemisia* on the basis of pollen have been unsuccessful (cf. Cawker 1983). Determining which *Artemisia* species were of major importance in glacial times is largely intuitive. The classic "sagebrush" of the west, the shrub *Artemisia tridentata*, is often considered an unlikely candidate. However, it does occur today in Alberta and British Columbia and has a cold-requiring ecotype, *A. tridentata* var. *vaseyana* that occurs in alpine zones. *Artemisia trifurcata* and *A. scopulorum* also occur in alpine zones. *Artemisia arbuscula* and *A. cana,* both similar to *A. tridentata,* are other possible candidates, as is the ubiquitous herb, *A. frigida*. Unfortunately we cannot yet tell which of these species is represented by full and late-glacial pollen spectra and we will not really understand what "high" *Artemisia* means until we can, if ever, separate species reliably.

5.3 Mitchell and Strubel Lakes

5.3.a Full-glacial Vegetational Reconstruction

(Pollen assemblage zones Ml-1 and Sl-1)

The basal pollen assemblage zones of both Mitchell and Strubel lakes are characterized by open-ground, herbaceous taxa including *Artemisia*, Gramineae and Cyperaceae. *Salix* and *Populus* are also important components of the pollen spectra. Other woody taxa are not well represented, although low sporadic counts of *Alnus, Betula, Juniperus* and occasionally, *Shepherdia canadensis* and *Ceonothus* were recorded.

These lakes, approximately one kilometer apart, do show some consistent differences in the pollen assemblages. Percentages of *Artemisia* and *Salix* tend to be higher at Mitchell Lake whereas percentages of Gramineae, Cyperaceae, and *Populus* are higher from Strubel Lake. These contrasts may well reflect local geomorphological differences between the basins in which the two lakes are found. The ground in the immediate vicinity of Mitchell Lake, within a deep basin with steep-sided slopes, may have been more conducive to shrub than grass vegetation; whereas Strubel Lake, within a shallower depression among sand dunes, had less steep slopes, gradual basin changes, and possibly moister ground conditions.

Several taxa present at Strubel Lake but absent from Mitchell Lake, e.g., *Actaea*, *Astragalus*, Compositae, *Galium*, and *Spirea*, may indicate moister meadow-like conditions in the area immediately surrounding Strubel Lake. Alternatively, as several of these taxa are represented by a single event, they may be statistical aberrations; i.e., they are not necessarily absent in the actual vegetation near Mitchell Lake, just absent from the pollen representation of that vegetation.

Pollen influx was not calculated for Strubel Lake due to rejection of the radiocarbon dates. However, when prominent pollen spectra are matched, and dates from Mitchell Lake extrapolated, rough influx values for Strubel Lake are comparable to values calculated for Mitchell Lake. Only Mitchell Lake influx values are referred to in the following discussion.

The basal pollen assemblage zones of both lakes coincide with highly minerogenic sediments, primarily fine clay and silts. The extremely low pollen influx of these largely nonarboreal Late Pleistocene pollen assemblages occurring in highly minerogenic sediments with low organic matter content suggest at least three possible interpretations:

1) that the record indicates spare fellfield-like tundra, similar to that interpreted by Cwynar (1982) for the Yukon and Schweger (1985) for western Alberta during the full-glacial,

2) that the record indicates a pioneer parkland community, i.e., one that is primarily nonarboreal except for the presence of *Populus*, which invaded the area soon after deglaciation (e.g., Lichti-Federovich 1970; MacDonald 1982).

3) that the record indicates a cold semiarid *Artemisia* steppe similar to those reported by Markgraf and Lennon (1986) for the Powder River Basin of Wyoming, and Barnosky (1989) for northwestern Montana.

There is an apparently widespread tendency to interpret herb zone pollen assemblages as tundra of varying types. Justification generally centers on the low pollen influx, nonarboreal characteristics, and low organic matter content of such assemblages, along with presumption of a cold climate. Such characteristics may in fact indicate tundra, but they also may indicate a very sparsely vegetated arid steppe. As arctic or alpine tundra indicators (e.g., *Dryas, Arctostaphylos alpina/rubra, Rubus chamaemorous*) are absent from the Strubel and Mitchell Lake basal pollen assemblage records while a complex of grassland and/or steppe indicators (e.g., *Artemisia*, Gramineae, Tubuliflorae H.S., *Ambrosia* type, Chenopodiaceae-*Amaranthus*, and *Sarcobatus*) are present in significant amounts, I reject characterizing the assemblage as tundra.

Determining whether pioneering parkland or *Artemisia* steppe best describe the vegetation is more difficult. The two are not as diametrically opposed as they may first appear. Modern pollen surface samples point to a general observation that *Populus* is underrepresented in modern pollen assemblages, and it is difficult to estimate its abundance on the landscape. A pioneering parkland vegetation might be composed of cold *Artemisia* steppe in the open well-drained areas, *Salix* and Cyperaceae in lower areas with impeded drainage, and *Populus* in sheltered areas such as river floodplains and valleys. Although this scenario is plausible, I feel that other evidence to be discussed later indicates a climate too severe to support significant arboreal elements.

Consequently, I interpret the basal herb zone of ML-1 and SL-1 as a cold semiarid steppe dominated by *Artemisia*. First, it must be pointed out that choosing this reconstruction does not necessarily mean a rejection of the concept of a pioneer vegetation. The vegetation in the vicinity of Mitchell and Strubel lakes could be either a pioneering vegetation or a vegetation characteristic of an unstable periglacial environment, which would be the situation if the region remained unglaciated throughout the Late Wisconsinan.

It also must be stressed that labelling the vegetation as a cold semiarid *Artemisia* steppe by no means implies a uniform homogeneous environment. Although *Artemisia* is clearly dominant, with values up to 78%, it is not the only taxa in the record. *Salix* and Cyperaceae would have been present in moister lowland areas. *Sarcobatus* may have been common, especially on the seasonally dry edges of such moist areas. And as previously mentioned, low occurrences of *Populus* do indicate its presence, likely on river floodplains and other protected areas. While barely registering at Mitchell Lake, *Populus* ranges as high as 7% at Strubel Lake, possibly indicating local abundance on the mesic flat land surrounding the lake. Interestingly, *Actaea*, present at Strubel Lake, is today associated with poplar woods (Cormack 1977:95).

A patchwork mosaic environment also would be encouraged by the microsite variability found on the hummocky moraine that is characteristic of the region. On such terrain it is possible to move from xeric sites on higher ground and south-facing slopes to hydric sites in enclosed depressions within short distances. The contrasts between the Mitchell and Strubel Lake records amply illustrate such variability.

The distinguishing feature of the environment would have been extensive areas characterized by very spare, discontinuous xeric vegetation composed primarily of *Artemisia*, with grasses and various open ground herbs, e.g., Chenopodiaceae-*Amaranthus*, *Thalictrum*, *Epilobium*, *Eriogonum*, *Plantago*, *Castilleja*, and *Heuchera*. All of these taxa occur in the basal zones of Mitchell and/or Strubel Lakes.

Sarcobatus, Tubuliflorae high spine, *Ambrosia* type, and Liguliflorae occur regularly in grassland assemblages and only rarely or infrequently in arctic and/or alpine tundra assemblages (Lichti-Federovich and Ritchie 1968). Vance (1986b) interpreted the presence of these taxa at Eaglenest

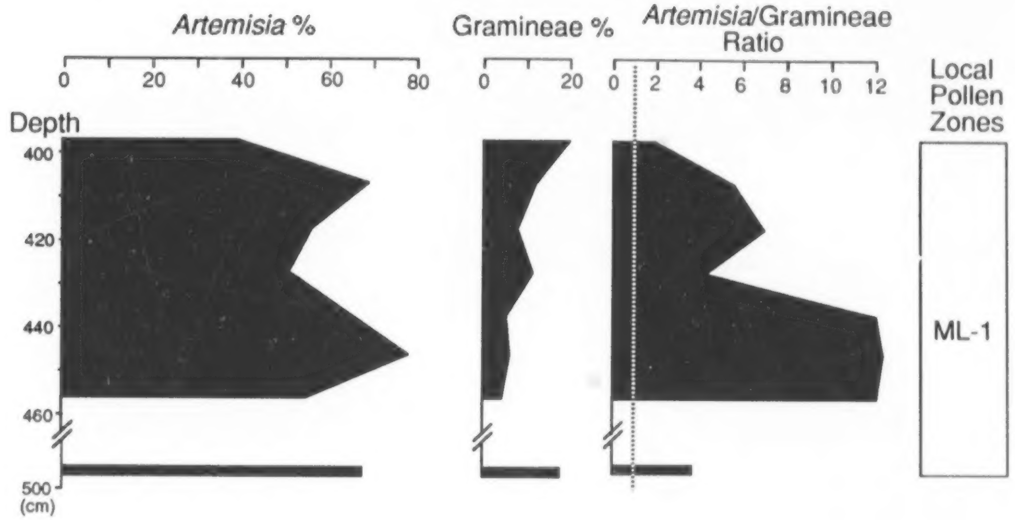
Lake as a form of grassland or parkland vegetation. My characterization of the Mitchell and Strubel basal assemblages as *Artemisia* steppe rather than grassland is supported both by very high percentages of *Artemisia* (maximums of 62 to 78%), and high *Artemisia*:Gramineae ratios. *Artemisia*:Gramineae ratios are consistently greater than one for Mitchell Lake, and generally greater than one for Strubel Lake (Fig. 5.1).

As Barnosky (1984) stated in reference to the Pacific Northwest, the "extent to which changes in the precipitation gradient may have restructured past plant communities has not yet been considered" (1984:619). High *Artemisia* percentages and *Artemisia*:Gramineae ratios are a reflection of such restructuring. As discussed earlier, very high percentages of *Artemisia* (ca. 40 to 60%) and high *Artemisia*:Gramineae ratios are characteristics of the *Artemisia*-dominated vegetation found through the northwestern plains, from intermountain shrub steppes to desert scrub and semi-desert. These associations have very low ground cover, always less than 100% (unlike grassland), and often as little as 10 to 50%.

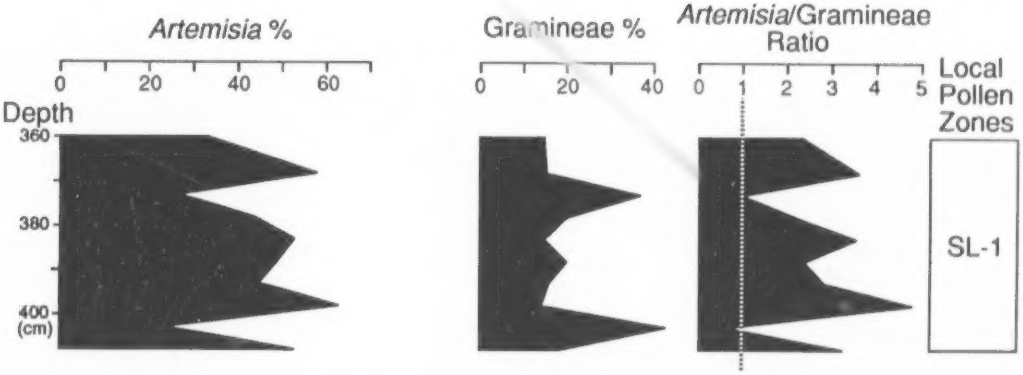
The extremely low pollen influx along with the highly minerogenic nature of the sediments of both lakes suggest an environment with spare discontinuous xerophytic vegetation and significant areas of dry mineral soils. The presence of several open ground taxa (e.g., *Epilobium, Plantago*), and a high proportion of degraded *Artemisia* grains support such an interpretation. Such sparse vegetation is an adaptation to severe moisture stress, which is why high *Artemisia*:Gramineae ratios, i.e., *Artemisia* dominated vegetation, is an accurate indicator of aridity. Soil moisture rather than temperature is the critical environmental factor that determines the composition and distribution of plants in the steppes and

Figure 5.1. *Artemisia* : Gramineae ratios as Compared to Percent Curves

a) Mitchell Lake



b) Strubel Lake



grasslands. While grasses are often vulnerable to a lack of spring and summer rains, *Artemisia* has long been noted to increase markedly under drought conditions (North 1976).

5.3.b Late-Glacial Vegetational Reconstruction
(Pollen assemblage zones ML-2 and SL-2)

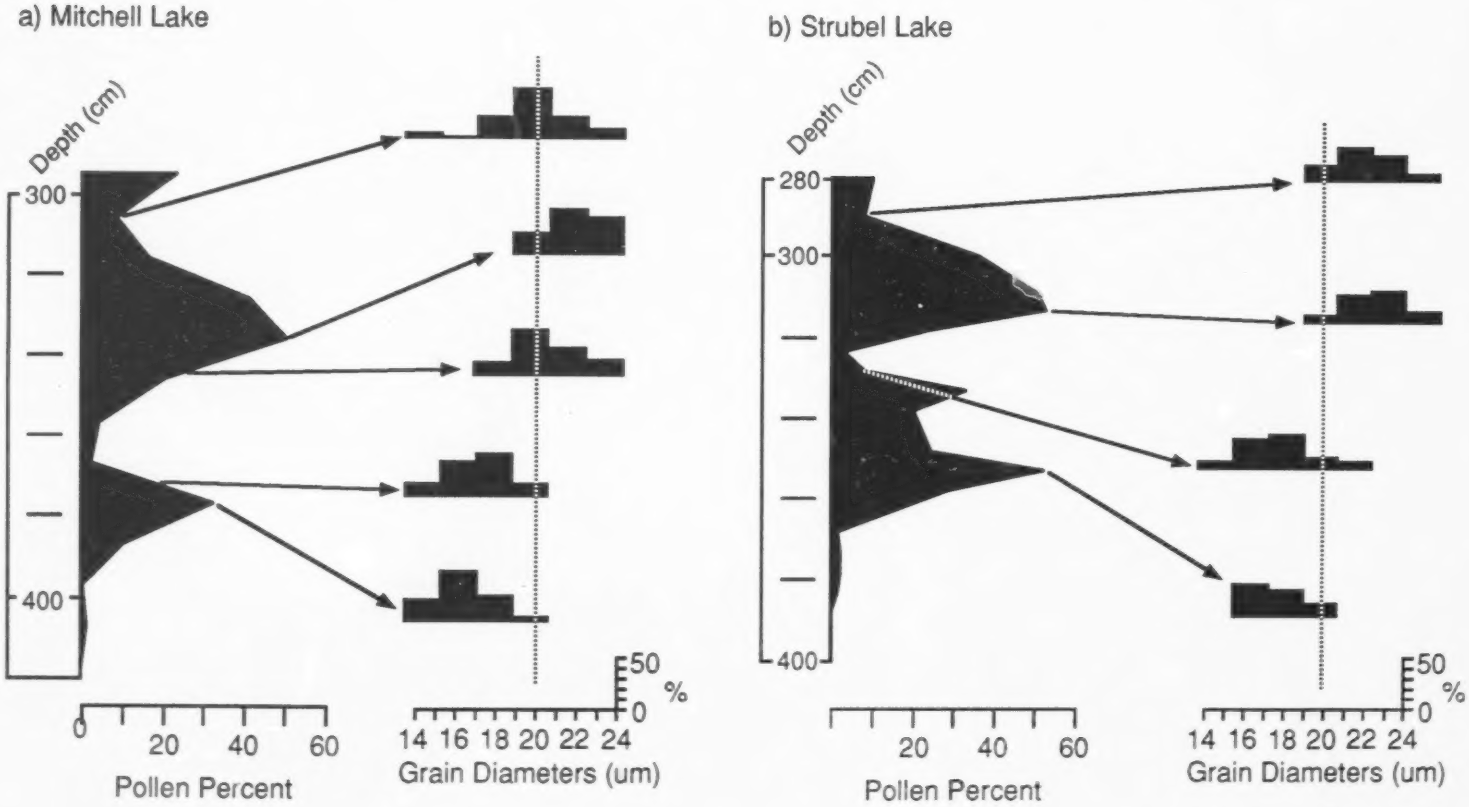
This zone is distinguished from the previous zone by the appearance of birch. *Betula* pollen grain diameters from zones ML-2 and SL-2 (lower birch peak) are less than twenty microns (Fig. 5.2). Although size measurements of birch pollen grains are not thus far proven to distinguish between shrub and arboreal species (Ives 1977; Edwards 1988), many palynologists are optimistic that grain size measurements do in fact indicate at least relative contributions of different-sized species to the pollen assemblage. This optimism is based on two lines of circumstantial evidence:

1) the correlation of shrub-sized birch with nonarboreal pollen assemblage zones and arboreal sized birch with arboreal assemblage zones, and

2) the fact that the macrofossil evidence has thus far always supported the pollen data (Ritchie 1987). Thus the *Betula* pollen from zones ML-2 and SL-2 may represent shrub birch.

Birch pollen, though very abundant in terms of percent, is actually represented by relatively low influx rates, especially when compared to the second birch peak, which occurs later in ML-3 and SL-3. The high percentage rates are likely due to overrepresentation, as shrub birch is very prolific, with 2 to 3% ground cover registering 13 to 18% as pollen in lake sediments (Ritchie 1987). Additionally, although *Artemisia* and Gramineae appear to decrease significantly in percent at both lakes, their influx values

Figure 5.2. *Betula* Diameter Measurements from Mitchell and Strubel Lakes



a) Mitchell Lake

b) Strubel Lake

indicate no real change. This suggests that the birch peak does not represent a replacement of herb or steppe vegetation, but instead an addition of birch to the existing vegetation assemblage (Cwynar 1982).

Percentages of birch are significantly higher at Strubel Lake than at Mitchell Lake, perhaps reflecting increased moisture availability. Percentages for *Salix* are also higher at Strubel Lake than Mitchell Lake as they were in the previous zone. In addition, *Corylus* is at a maximum at Strubel Lake in this zone. These shrubs may have formed a thicket growing on boggy areas created by lowering of lake level. Alternatively, *Corylus* may have been associated with poplar groves. Although *Populus* barely registers at Mitchell Lake, at Strubel Lake it reaches a maximum of 12% in this zone, suggesting local abundance in sheltered areas.

Evidence for lowering of lake level at Strubel Lake is indirectly inferred from conditions at Mitchell Lake. Throughout this zone, Mitchell Lake is characterized by the deposition of increasingly marly sediment. The sediment changes gradually from clay to marly clay just below the base of this zone, becoming true marl by the middle of the zone. The marl deposition may be due to the lake gradually becoming more shallow. Marly sediment is often associated with arid conditions, when evaporation exceeds precipitation (Birks and Birks 1980), and suppresses water levels. Although Strubel Lake experiences no corresponding change in lithology, it likely also experienced lowered water levels. Both lakes register significant increases in Cyperaceae, and at Mitchell Lake, the Cyperaceae maximum occurs in this zone. Extensive sedge communities may have developed on exposed organic muds or shallow water flats around the lake.

Triglochin, *Rumex*, *Menyanthes*, and *Gentianella*, limited to this zone, indicate local boggy or marshy conditions and/or moist meadows. Taxa indicative of dry or disturbed conditions occur (e.g., *Huechera* at Strubel Lake and *Chenopodiacaceae*-Amaranthus, *Crucifer*, Tubuliflorae high spine and low spine, and *Plantago* at Mitchell Lake), with some reaching their maxima in this zone. This distribution supports arguments for mosaic structured vegetation.

In summary, zones ML-2 and SL-2 appear to represent vegetation similar to the both the steppe of the previous zone and birch shrub tundra; using the term tundra in a physiognomic sense. There would have likely been an *Artemisia* dominated herb assemblage on uplands, while birch, if the shrub ecotype, would have occurred on moderately drained slopes and moist surfaces. Sedges, willows, and various moist ground taxa were more abundant, indicating an increase in moist areas perhaps due to lowered lake levels exposing lake beds. *Populus* would have been present on outwash surfaces, sheltered lake shores, and river terraces. Vegetation cover would have been more extensive, as indicated by the higher pollen influx, higher organic matter content, and decreasing minerogenic nature of the sediments, as compared to the previous zone. Yet several open ground taxa and continued relatively low influx, ca. 300 g cm^{-2} yr^{-1}, comparable to modern low arctic dwarf shrub tundra (Ritchie and Lichti-Federovich 1967), indicate areas of bare ground were still present.

5.3.c Post-glacial Vegetational Reconstruction

(Pollen assemblage zones ML-3A and SL-3A)

Over the early part of this period the vegetation around Mitchell and Strubel lakes remained the same as in the preceding period. Shortly after 11,500 years ago, however, *Picea* arrived in the region, and there were other significant vegetational changes. *Picea* percentages rise abruptly to 43 and

68% at Mitchell and Strubel Lake, respectively. Several taxa including *Salix*, Gramineae, and *Artemisia* decrease in percent but not significantly in influx values. *Betula* decreases drastically to 2% and ca. 30 g cm^{-2} yr^{-1}. *Corylus* increases, as does *Alnus*, which rises to 6%, its maximum for both lakes. *Pinus* values of 20 to 40% indicate the taxa may be nearing the region but is not yet present locally as surface samples in modern grassland in Alberta where *Pinus* is absent may register up to 50% *Pinus* pollen (MacDonald and Ritchie 1986).

While Cyperaceae decreases at Mitchell Lake to a minimum of 2%, at Strubel Lake it increases enormously to a maximum of 95%, calculated outside the sum. Such high values at Strubel Lake while absent at Mitchell Lake one kilometer away indicate locally extensive sedge communities — perhaps sedge meadows or marshes.

Cyperaceae values are at their most extreme near the end of this period, when summer insolation was at a maximum and many lake basins in Alberta were empty or ephemeral ponds (Schweger and Hickman 1989). As sand dunes are highly permeable, water level depression is determined primarily by ground water level. Seasonal shrinkage of Strubel Lake would have exposed extensive shallow areas of the basin and allowed the development of relatively lush sedge stands. *Typha* is also present throughout this zone. Wright et al. (1985) interpret a similar assemblage in a similar situation, i.e., sand dunes in Nebraska, as a sedge/cattail marsh due to low lake levels caused by early-mid Holocene aridity. The steep bathometry of its basin would have prevented similar conditions at nearby Mitchell Lake.

Although the evidence for water levels is somewhat confusing, pointing to lower or at least seasonally lower levels at Strubel Lake, and maintained levels at Mitchell Lake, both might be accurate. Mitchell Lake is a deep narrow basin located 30 m lower in elevation than Strubel Lake. Mitchell Lake might have been better able to maintain water level, while Strubel Lake, broader and shallower over large areas of its basin, would have been more susceptible to the effects of increased summer insolation levels.

Pollen spectra similar to those of SL-3A and ML-3A are often compared to modern forest tundra, and in some aspects are indeed similar, e.g., high *Picea*, low *Pinus*, with total influx values of 1000 to 2000 g cm^{-2} yr^{-1} (Lichti-Federovich and Ritchie 1965; Birks and Birks 1980). However forest tundra is also often characterized by high *Betula* and *Alnus* values (Birks et al. 1975), which are not present in the Strubel and Mitchell lake cores in this zone. Ultimately, it is the physiognomic descriptions, and not comparable species composition, of forest tundra that seem most applicable to the pollen spectra of ML-3A and SL-3A, e.g., the common references to discontinuous stands of spruce. Ritchie (1974:387) describes forest tundra as "characterized by clumps or sparse stands of spruce in hollows and on slopes in a landscape otherwise clad with various tundra types." But, instead of various tundra types, the vegetation near Rocky Mountain House probably included various steppe, grassland and prairie types. As previously noted, although *Artemisia* and Gramineae decreased notably in percent, decreases in influx are minimal. In addition, other open ground herbaceaous taxa, e.g., Tubuliflorae high spine, *Thalictrum*, Chenopodiacaceae-*Amaranthus, Crucifer,* Liguliflorae, and *Sarcobatus*, register increases in influx. For these reasons open spruce woodland or parkland seems a more appropriate reconstruction than forest-tundra.

Davis (1967:224) hypothesizes open spruce woodland for a similar pollen zone at Rogers Lake, Connecticut, based on its resemblance to open spruce woodland in northern Quebec. Vance (1986b) feels that open spruce woodland characterized his zone EL-2 at Eaglenest Lake in northern Alberta, approximately 600 km northeast of Rocky Mountain House. He argues for open spruce forest on the basis of sustained herbaceous representation at a higher level than in the following boreal forest zone, and because pollen influx is relatively low (ca. 2000 g cm^{-2} yr^{-1}).

Total influx values from zone ML-3A average 1330 g cm^{-2} yr^{-1}, while spruce influx averages 550 g cm^{-2} yr^{-1}. Modern spruce pollen influx values of approximately 600 g cm^{-2} yr^{-1} represent a frequency of 115 m^2 per km^2 (measured as cross-sectional area of all stems greater than 2.5 cm in diameter 1.6 m above the ground per unit of area), which suggests very open conditions (Davis et al. 1973:21). Lamb (1980) used 2000 g cm^{-2} yr^{-1} as a lower threshold value to distinguish open spruce woodland from closed spruce forest. Although influx for individual tree species varies from one region to another and both these examples are from eastern North America, these comparisons strongly suggest a significant openness in the vegetation represented by the Strubel Lake and Mitchell Lake pollen spectra.

There would have been open areas dominated by *Artemisia*, *Gramineae* and other herbaceous plants, creating a type of steppe or grassland-spruce forest mosaic similar to modern vegetation assemblages in the mountains of Wyoming. The present vegetation of Yellowstone Park in the vicinity of Blacktail Pond, elev. 2018 masl, is described as islands of boreal conifers within an *Artemisia* scrub steppe, with a few stands of poplar (Gennet and Baker 1986:62). In the Wind River Range of Wyoming, *Artemisia* communities form small parks within the subalpine fir zone in high intermountain valleys and on southwestern slopes (Arno 1984:196). Such communities may be remnants of a similar vegetation assemblage in glacial times. Late-glacial pollen assemblages from Wyoming indicate conifer woodlands mixed with steppe taxa in parkland habitats (Baker and Waln 1985). The pollen evidence is supported by data from pack rat midden analysis in the Great Basin indicating that *Artemisia tridentata* and other steppe elements grew at the same sites as boreal conifers in late-glacial times (Spaulding et al. 1983).

In summary, during this period the vegetation in the vicinity of Strubel and Mitchell lakes was characterized by a largely nonarboreal pollen spectrum that also included significant *Picea*. It can be speculated that mesic sites had a mixed *Picea*-Gramineae parkland or woodland, hydric sites supported willow-grass or shrub marsh, xeric and south-facing slopes had *Artemisia*-Gramineae-herbaceous open prairie communities, and north-facing slopes supported locally dense stands of *Picea*.

5.4 Nordegg Pond

5.4.a Post-Glacial Vegetational Reconstruction

(Pollen assemblage zone NP-1)

At Nordegg Pond in the foothills, 80 km west of and 150 m higher in elevation than Rocky Mountain House, the basal pollen assemblage is characterized by high percentages (to 75%) of *Artemisia*. Other significant herbaceous taxa characteristic of open mineral soil or disturbed ground include Gramineae, Cyperaceae, Tubuliflorae high spine, *Plantago*, Rosaceae, Chenopodiacaceae-*Amaranthus*, and *Anemone*. Herbaceous taxa restricted to this zone include *Phacelia*, characteristic of dry open disturbed areas and rocky slopes, and *Gentianella*, *Galium*, *Valeriana*, and Leguminosae, which are commonly found in moist woods, meadows and bogs. These taxa likely indicate moist meadowlike conditions in the immediate vicinity of Nordegg Pond.

Populus reaches a maximum in this zone with percentages of 1 to 2%. Though low, these values do suggest its presence. *Shepherdia canadensis*, frequent in balsam poplar forest but poorly represented in pollen (Birks 1977) also reaches a maximum of 2% in this zone. Overall, the pollen record appears to represent an aggressive pioneering parkland steppe vegetation. *Artemisia*, with extremely high influx values, probably formed steppe communities with Gramineae and other herbs on xeric and south-facing bare mineral soils. *Salix*, Cyperaceae and assorted moist ground herbs grew in mesic to hydric sites while north-facing slopes and sheltered floodplains and valleys likely supported *Populus*.

Total pollen influx values are very variable, ranging from 900 to 9000 g cm^{-2} yr^{-1} and averaging 3750 g cm^{-2} yr^{-1}. Such values are higher than those characteristic of recent tundra vegetation and are comparable to those recorded for recent prairie and parkland vegetation (Barnosky 1985: Birks and Birks 1980). Overall the character of the vegetation in the vicinity of Nordegg Pond ca. 12,000 to 10,200 years ago appears to have been primarily a pioneering *Populus* parkland with extensive steppe-like areas.

5.5 Regional Paleoenvironmental Summary

5.5.a Full-Glacial (ca. 18,000 to 16,000 B.P.)

Areas of land in the upper North Saskatchewan drainage basin that were not covered by ice and/or glacial lakes supported a cold semi-arid *Artemisia* steppe vegetation as described for pollen assemblage zones ML-1 and SL-1. This sparse discontinuous xeric vegetation, dominated by *Artemisia*, included grasses and assorted open ground herbs and forbs.

Approximately 50% of the total area of the drainage basin would have potentially been open to support vegetation during this period, including

1) areas never covered by Late Wisconsinan ice (ca. 18% of total basin area); and

2) areas of recently stagnated and subsequently debris-covered ice (ca. 32% of total basin area).

It should be noted that the dates from Mitchell Lake are insufficient to establish whether the physical environment in the eastern portion of the North Saskatchewan drainage basin was characterized by extant periglacial or newly exposed pioneering substrates. The 17,960 +/- 160 yr B.P. (TO-574) date at Mitchell Lake does not definitely date the glacial deposits in the area. There are two possible alternatives:

1) Late Wisconsinan Laurentide ice advanced westward over the area and subsequently retreated east of the area (far enough to allow for drainage of Glacial Lake Caroline) during the Late Wisconsinan but prior to ca. 18,000 years ago; i.e., 22,000 to 18,000 yr B.P., as was proposed earlier.

2) the area was not glaciated throughout the Middle and Late Wisconsinan as suggested by Rutter (1984) and Bobrowsky et al. (1990). That the area may not have been covered by glacial ice does not imply it was necessarily open ground, as it would initially have been flooded by glacial meltwater dammed between the ice masses, (e.g., Boydell's 1978:Fig.14, first stage of development of Glacial Lake Caroline.

The stratigraphy of the lowermost 150 cm of the Mitchell Lake core and lowermost 100 cm of the Strubel Lake core, below the pollen-bearing sediment, shows high percentages of sand, silt, and clay. This can be interpreted as a relatively rapid deposition of lake sediments, washed out of unconsolidated glacial deposits during the initial stages of recession of a

Late Wisconsinan Laurentide ice sheet, and the drainage of Glacial Lake Caroline when a vegetation-free landscape could have undergone a high rate of modification.

Somewhat consistent carbonate values of 5 to 10% in the lowermost section of both cores may indicate carbonate leaching from calcareous till. High carbonate values are often reported from lake sediment deposited soon after deglaciation, when sparse vegetation cover would have allowed significant leaching of unweathered tills (MacDonald 1982:30). A carbonate peak ca. 16,000 years ago in the Mitchell Lake core reflects both the marly nature of the clay and the abundant molluscs. Both the marly conditions and molluscs, in particular the very abundant *Sphaerium* and *Psidium*, indicate extremely low water at this time. The sedimentary data suggest that whether ultimately periglacial or post-glacial, the landscape was characterized by extensive areas of bare mineral soils.

There is climatic evidence that supports drought conditions in the interior Pacific Northwest and northern Great Plains during full glacial times. Climatic modeling simulates a split westerly jet stream with branches directed north and south of the ice sheets. The southern branch was deflected too far south to bring moisture to the northern plains, instead delivering it to the Southwest and Great Basin (Kutzbach and Wright 1986). In any case the Pacific air masses would have had less moisture than today as colder ocean surfaces would have resulted in less evaporation and thus a lower moisture content in the air (CLIMAP 1976; Donn and Ewing 1968: Barnosky 1984) and caused a large area of soil dryness to develop in the interior Pacific Northwest and northern Great Plains (Broccoli and Manabe 1987:298).

Permafrost indicators suggest a mean annual temperature at least 5 to 13^{0}C below modern levels and perhaps colder adjacent to the ice sheets, with low precipitation and windy conditions (Mears 1981). Both Mitchell and Strubel and other lakes in the northern plains have extremely low sedimentation rates in their lower zones. It has been suggested that this is likely the result of long-lasting ice cover (Funder and Abraham 1988). Despite the cold, stronger radiation in the lower latitudes may have caused higher evaporation stress than is typical of modern northern latitude arctic climates. The short warm summers with little precipitation could allow soils to thaw deeply enough to provide a well-drained, dry upper surface. The strong winds resulting from stationary highs over the ice masses, and the steepened temperature gradient from north to south (Ruddiman and Wright 1987; 1991), also would contribute to both dry soils and an open landscape. Thus the character of the landscape was likely cold, dry, and windy.

The proposed vegetation for such a climate is one with a greatly restricted forest cover resulting in essentially a merging of the semiarid steppe and the alpine tundra in one large ecotone (Kutzbach and Wright 1986: Barnosky et al. 1987b). This scenario is consistent with the vegetational and environmental conditions proposed for the upper North Saskatchewan valley during full-glacial times. The sedimentary evidence and pollen data are consistent with the climatic reconstruction of an open arid landscape (Wright 1991). Perhaps the phrase "*Artemisia* semi-desert" would indicate the extreme dryness and lack of vegetation better than "*Artemisia* steppe." Although the term desert commonly suggests warmth; this would of course be a cold desert.

Although vertebrate mammal remains, including mammoth, bison, bighorn sheep, and horse, have been reported in Middle Wisconsinan (ca

40,000 to 22,000 B.P.) deposits from several localities in the vicinity of the ice-free corridor (Harrington 1978; Churcher and Wilson 1979; Burns 1984, 1989, 1990), no vertebrate faunal assemblages from within the corridor date to the full-glacial or for several millennia afterward. In fact, "dates on vertebrate recoveries from Alberta are virtually nonexistent for the period from 22 to about 12 ka" (Burns 1989:28). As Ives et al. (1989a:10) state, "it is reasonable to speculate that the severe physical conditions associated with the late Wisconsinian maximum might have virtually eliminated the large mammal community in many regions of the corridor."

5.5.b Late-Glacial (ca. 16,000 to 12,000 B.P.)

Areas of land in the upper North Saskatchewan drainage basin that were not covered by ice and/or proglacial lakes supported a shrub steppe vegetation characterized by *Artemisia*-dominated herb assemblages, shrub birch, and *Populus*. Pollen influx values and open vegetation indicators indicate that areas of bare mineral soil were still significant. The area of the drainage basin that would have potentially been open to support this vegetation increased from 55% ca. 16,000 years ago to 65% by 12,000 years ago, with much of the area consisting of bare mineral soils exposed by downwasting stagnant ice and subsequent debris accumulations. The value of 65% is essentially the maximum possible, as approximately 35% of the area of the basin consists of elevations above 1850 m that are presumed to be mostly nonvegetated.

Other than the addition of *Betula* to the vegetation assemblage, most characteristics of the environment, including virtual absence of faunal remains, are similar to the previous period. The climate also would at first have been comparable to the full-glacial, with gradual amelioration in temperatures beginning ca. 14,000 B.P. associated with changing orbital parameters and escalation of deglaciation.

5.5.c Post-Glacial (ca. 12,000 to 10,000 B.P.)

By the beginning of this period all land below 1850 m in elevation is assumed to have been potentially open to vegetation, although evidence of the past vegetation differs at different sites in the drainage basin. In the lower eastern portion of the basin, represented by Mitchell and Strubel Lakes, vegetational succesion is well under way, and by 11,400 B.P. there was an open spruce parkland or woodland vegetation as described for zones ML-3A and SL-3A above. Such vegetation was characterized by a largely nonarboreal pollen spectrum that included *Picea*, resulting in a type of steppe or grassland/spruce forest mosaic. The western higher elevation portion of the basin, as represented by Nordegg Pond, reveals pollen characteristic of an aggressive pioneering parkland steppe vegetation.

The open spruce woodland reconstructed for the post-glacial as described for zones ML-3A and SL-3A above is comparable to vegetation found currently in the mountains of Wyoming and interpreted for late-glacial pollen spectra from the northern Great Basin. What might these times and places (high altitude modern Wyoming, late-glacial northern Great Basin, and post-glacial Alberta) have in common that could explain observed similarities in vegetation? Vance (1986b:18) notes that zone EL-2 from Eaglenest Lake resembles "recent pollen spectra in the boreal woodland of Labrador, where the open forest structure is thought to result from a soil moisture shortage caused by permafrost." He feels that since the growing season during post-glacial times was likely warmer than at present and organic soils would not have yet developed, that permafrost was unlikely to have been the cause of the open forest conditions of EL-2 times. Instead he proposes that soil moisture changes may have been caused by a warmer and drier climate (Vance 1986b:18).

Summer insolation reached its maximum in this period (Schweger and Hickman 1989; Wright 1991). Data from paleoecological studies suggest warmer summers with summer drought periods occurred ca. 12,000 to 6,000 years ago in the northern middle latitudes (Zoltai and Vitt 1990). In addition, dry, southeasterly winds were likely maintained over the study area due to the southward deflection of westerlies by the remaining mass of the Laurentide ice to the east (Kutzbach and Wright 1986). Such conditions could have kept soil moisture under a threshold limit necessary for dense spruce forest, and simultaneously ensured abundant mineral soils were available for assorted herbaceous open-ground taxa.

Overall, the vegetation in the upper North Saskatchewan drainage basin ca. 12,000 to 10,000 years ago appears to have been characterized by a pioneering *Populus* parkland in the western higher elevations and a *Picea* woodland to the east, both with extensive steppe components. Such vegetation was the result of the interactions of substrate availability (e.g., final melting of stagnant ice in the Nordegg Pond area), soil moisture availability, temperature, windiness, and the varying migration rates of individual taxa. *Picea*, for example, would not have been absent from Nordegg Pond for climatic or edaphic reasons, but simply because it had not yet migrated from its source area to the east. Abundant vertebrate faunal remains dating ca. 11,500 to 10,000 years ago from several localities in the ice-free corridor region (Wilson and Churcher 1978; Churcher 1984; Driver 1988; Burns 1989) suggest this vegetation was in fact capable of supporting viable mammal populations during post-glacial times.

6. Physical Environment

6.1 Establishing a Geological and Paleogeographic Framework

In Chapter 2 various geological interpretations of the ice-free corridor from its inception as a concept circa 1933 up to Rutter's (1984) synthesis were presented. In the corridor region, as elsewhere in North America, "controversy surrounds the exact limits and chronology of Late Wisconsinan advances, with proponents of maximum and minimum glacial models sometimes 'staking all' on the interpretation of one or two crucial radiocarbon dates" (Fladmark 1983:27). Due to the complexity of the geological problems and the lack of reliable chronological data it is possible for different workers to come up with varying interpretations that are equally supported by the available evidence.

Rutter's (1984) scenario of a corridor closed throughout northeastern British Columbia but open to the north and south of this coalescence was the 'minimum' position of the time and was the geological baseline I worked with when choosing lake locations. The alternate model, i.e., an extensive maximum with coalescent ice from the Yukon to Montana, allowed for no full-glacial corridor at all. These two positions were both depicted on Prest's (1984) map of the Late Wisconsinan Glacier Complex. It should be noted that the maximum ice position "is in reality a net or accumulative frontal position, and there is considerable disagreement on the precise timing and synchroneity of advances of individual lobes up to that maximum position in different areas" (Fladmark 1983:22).

In recent years much new work has been done throughout western Canada in an attempt to clarify the Quaternary history of the area. Unfortunately, many basic issues concerning the extent and timing of Wisconsinan glaciation remain unresolved and it is still necessary to discuss the minimum and maximum positions of the opposing 'schools' of thought.

Sometimes the issue is depicted as drawn along international boundaries (cf. Reeves 1985), with Americans (e.g., Fullerton and Colton 1986; Carrara et al. 1986) on the side of the more extensive maximum, which calls for ice coalescence throughout the Late Wisconsinan, and Canadians (e.g., Stalker and Harrison 1977; Rutter 1984) on the side of a less extensive maximum (a "minimum maximum"), which allows for an ice-free corridor between the ice sheets. This is a situation that is not that surprising, considering that each group tends to be most familiar with the geological deposits on their side of the border, and because the minimum position hinges on interpretation of deposits in southern Alberta, whereas the maximum position depends on interpretation of deposits in northern Montana.

But it is by no means simply a disagreement between workers of two areas who are unfamiliar with each other's territory. There is in fact nowhere near a consensus among researchers in Canada or even within Alberta. Disagreement in Alberta is evident between geologists and geographers, as there is considerable difference between an approach that interprets geomorphology, as opposed to the geologic approach that interprets stratigraphy. Because of the different methodologies and lines of reasoning used, geologists, particularly recent graduates of the University of Alberta (e.g., Catto 1986; Bobrowsky 1988, 1989; Bobrowsky et al. 1987), often argue for a non-coalescent Late Wisconsinan maximum (Fig. 6.1), while Alberta geographers (e.g., Kvill 1985; Rains et al. 1990; Young et al. 1990) tend to support a more extensive Late Wisconsinan maximum that resulted in coalescence of the ice sheets (Fig. 6.2).

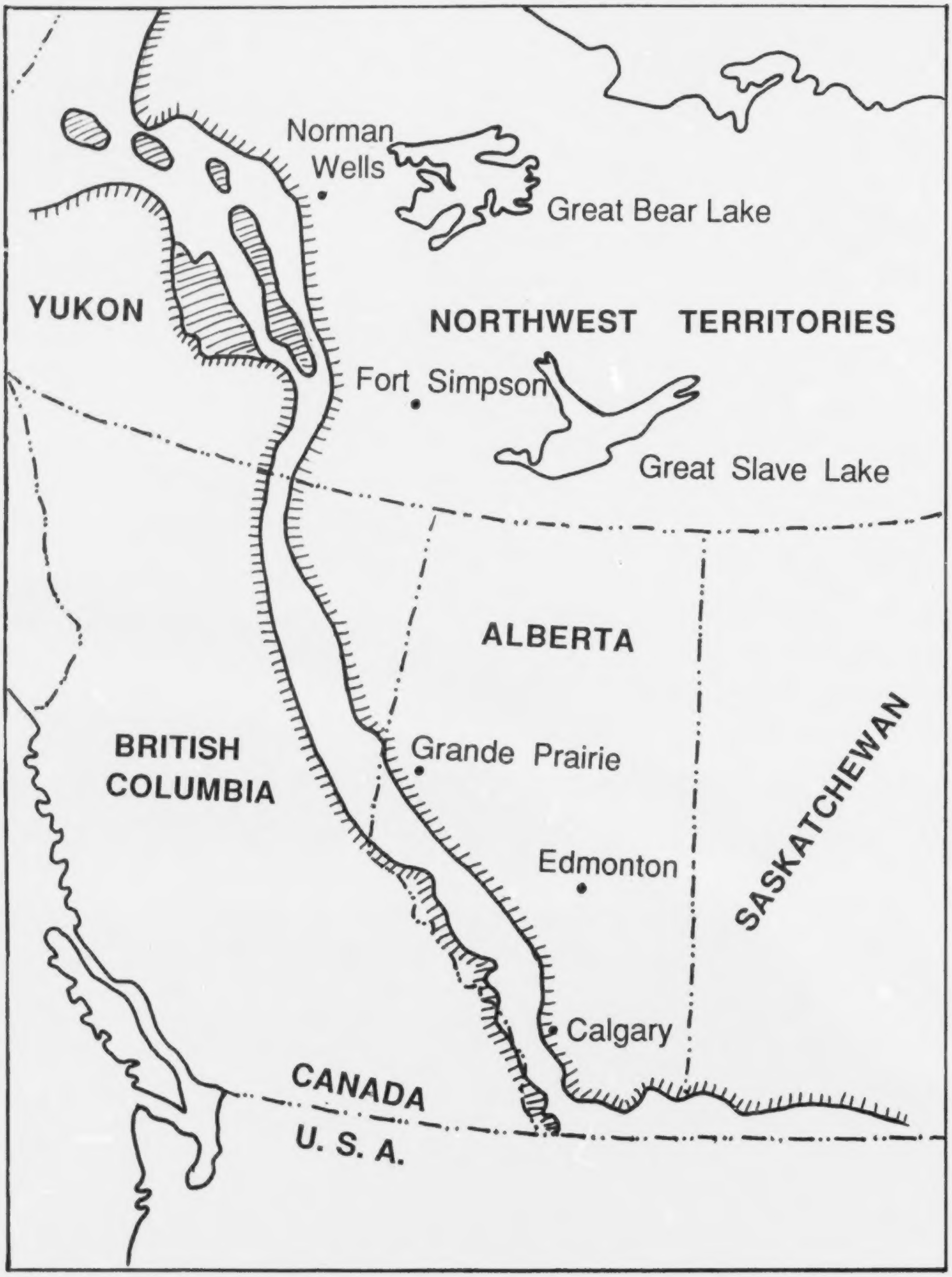
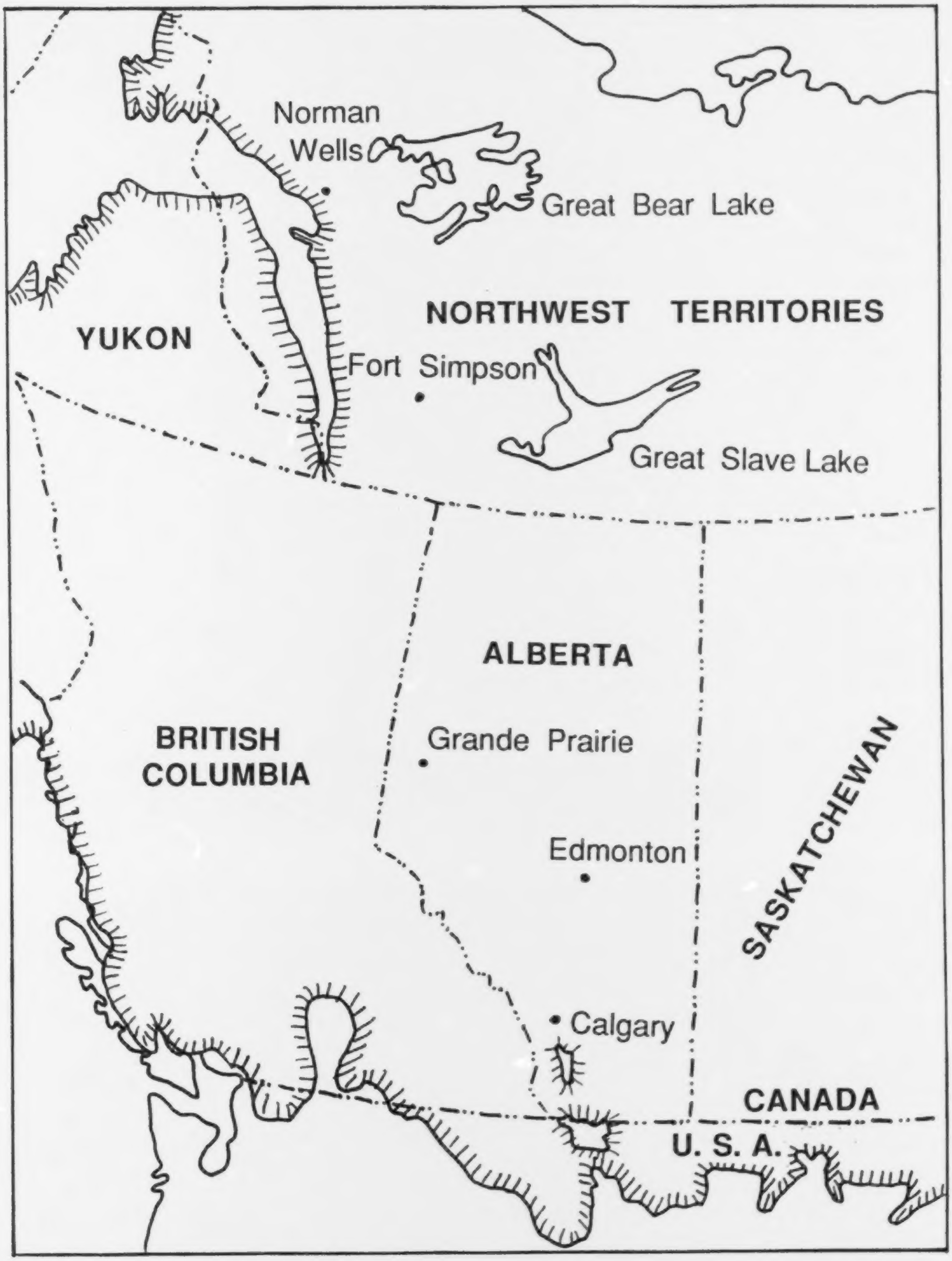

Norman Wells
Great Bear Lake
YUKON
NORTHWEST TERRITORIES
Fort Simpson
Great Slave Lake
ALBERTA
BRITISH COLUMBIA
Grande Prairie
Edmonton
SASKATCHEWAN
Calgary
CANADA
U. S. A.

Figure 6.1 "Minimum" Late Wisconsinan Maximum Ice Limits. After Bobrowsky et al. (1990:Figures 3,4 and 5). Reproduced with permission from P.T. Bobrowsky.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BRITISH COLUMBIA
Grande Prairie
Edmonton
SASKATCHEWAN
Calgary
CANADA
U. S. A.

Figure 6.2 "Maximum" Late Wisconsinan Maximum Ice Limits. After Dyke and Prest (1987:Map 1703A). Reproduced with permission from Les Presses de l'Universite de Montreal.

The pertinent arguments regarding coalescence versus noncoalescence of the ice sheets will be only briefly summarized here. For discussion purposes the corridor is divided into three sections as defined by Rutter (1984). These sections are the northern, north from the Yukon/Northwest Territories border to the unglaciated areas of Yukon and Alaska; the middle, from the Edmonton-Jasper region to the Yukon/Northwest Territories border; and the southern, from northern Montana to the Edmonton-Jasper region.

Rutter (1984) summarized evidence of the northern sector of the corridor area as indicating that Laurentide ice advanced to the mountain front of the Mackenzie and Richardson mountains, and that Cordilleran ice was largely restricted to the cores of the mountain ranges, resulting in an ice-free area along the eastern flanks of the mountains (Hughes 1972; Rutter 1984). Recent work in this area (Catto 1986; Duk-Rodkin 1989) supports this interpretation.

Rutter's (1984) scenario called for most of the middle section of the corridor from the Jasper area through northeastern British Columbia to have been closed due to the coalescence of Cordilleran and Laurentide ice in this area. The arguments for coalescence in this area were based on Mathewes' (1980) observations of a dilution in shield clasts east of the Laurentide maximum ice boundary, an under-till date of Middle Wisconsinan age, and a lack of end moraines.

Recent work in the Grande Prairie region of Alberta (Liverman 1989a, 1989b), and the Rocky Mountain Trench west of Fort St. John, B.C. (Bobrowsky 1988, 1989) has demonstrated that there was in fact no coalescence of ice in the middle portion of the ice-free corridor in Late Wisconsinan time. Liverman, Catto and Rutter's (1989) work reveals that only one Laurentide advance ever affected the Grande Prairie area and it did not coalesce with mountain or Cordilleran ice to the west. Evidence from ice directional indicators suggests that both montane and Laurentide ice advances in the area were unconstrained and overlapped in territory. Flutes and lineations formed by the ice issuing from the Redwillow Valley form a fan that extends east of the mountain/Laurentide till boundary. In addition, flutes are draped by lacustrine sediment formed in proglacial lakes dammed by Laurentide ice (Liverman 1989b). Also, Bobrowsky (1989) showed that ice was absent or severely restricted in the area west of Fort St. John throughout Middle Wisconsinan and most of Late Wisconsinan time until at least 15,000 years B.P., by which time Laurentide ice had begun its retreat. Thus the ice advances in the area were nonsynchronous and there was no actual coalescence of active ice.

The boundaries of the southern section of the corridor were defined by Rutter (1984) largely on the basis of arguments that Late Wisconsinan Laurentide ice reached only to the Lethbridge area (Stalker 1977), and that Cordilleran glaciers were restricted to the mountains (Stalker and Harrison 1977). Furthermore, accepting Stalker's (1977) interpretation of the Lethbridge moraine was interpreted to mean that evidence of deflection and coalescence of mountain ice and Laurentide ice in the Jasper-Hinton area (Roed 1975), Rocky Mountain House area (Boydell 1978), and Kananaskis area (Jackson 1977), must have been pre-Late Wisconsinan. That is, they must have been either Early Wisconsinan or pre-Wisconsinan in age, thus resulting in an open corridor between the ice sheets from Montana north to the Jasper area. Bobrowsky et al. (1990) accept this scenario for the southern portion; although several other researchers do not (cf. Rains et al. 1990; Young et al. 1989).

It is this southern section of the corridor that is the most complicated. Proponents of the extensive coalescent ice position rarely present detailed arguments concerning the middle and northern sectors of the corridor, but usually restrict discussion to the southern sector. For example, Young et al. (1990) feel that the apparently valid Late Wisconsinan dates on *Cynomys* (prairie dog) bones in a sub-till deposit atop the Hand Hills in southeastern Alberta also apply to such events as the landform of the hills themselves and the formation of glacial drumlins and flutes north of Calgary 100 km to the west. Rains et al. (1990) continue this line of reasoning. Although admitting that "the assumption that the limit indicators were all formed at the same time might be erroneous" (Rains et al. 1990:157), they argue that extensive coalescent ice characterized the southern sector of the corridor during the Late Wisconsinan.

There are at least two separate issues that need to be resolved. The first one is determining whether the Lethbridge moraine represents the maximum extent of the Late Wisconsinan maximum or whether the moraine is a retreat phase of the limit that was located farther south in Montana. The second issue concerns the timing of the ice event during which Cordilleran and Laurentide ice clearly coalesced along the eastern edge of the foothills. The question is not, as is often stated, whether there was coalescence; clearly there was coalescence, as ample evidence indicates (Roed 1975; Boydell 1978; Kvill 1985). The question is instead when the coalescence occurred, whether it was during the Late Wisconsinan or in fact took place earlier, either in Early Wisconsinan or pre-Wisconsinan time. Thus, while both issues pertain to maximum advances of ice in Late Wisconsinan times, the first is concerned primarily with the southward and westward extent of Laurentide ice, while the latter is primarily concerned with the eastward extent of mountain and/or Cordilleran ice.

It should be noted that acceptance of the evidence for coalescent ice presented by the above authors does not require acceptance of their arguments in their entirety. In particular there is a problem with the use of negative evidence to support an idea. For example, the lack of end moraines is often interpreted as unequivocal evidence for ice coalescence (e.g., Mathewes 1980). However, end moraines are not inevitable results of glacial activity. Speight (1940:134) noted that at an active mountain glacier in New Zealand, there was "no terminal moraine forming, all material [being] removed by the powerful Tasman River which issues from the glacier." Mountain glaciers issuing from major valleys of the Rocky Mountains would have been in a similar situation. In addition, the fact that the Laurentide ice was advancing into ponded water along most of its western border would surely have affected the nature of any moraine formation by draping the moraine deposits with glaciolacustrine sediments. This would be true not only in the disputed southern section of the corridor under discussion here but throughout the corridor area.

Although the two issues defined above concern different ice masses and therefore should be evaluated separately, they are often combined in various arguments. For example, Rutter (1984) argues that accepting Stalker's (1956, 1977) interpretation for the stratigraphic position of the Erratics Train advance and its correlation with the "mixed till" of central Alberta, means that the evidence of coalescence must date prior to the Late Wisconsinan. The implication is that a limited Laurentide advance and extensive ice coalescence are mutually exclusive events, which is not necessarily the case. In another combination of the issues, proponents of the extensive ice advance often assume that if the Late Wisconsinan

Laurentide maximum reached into Montana, this interpretation somehow implies that the coalescent ice advance was also Late Wisconsinan; which is also not necessarily the case. Or they assume that coalescence in the Athabasca Valley area necessarily means coalescence throughout southwestern Alberta because of the presumed association of the Athabasca "mixed" till and the famous Erratics Train of Alberta, which can be traced back to Mt. Edith Cavell in the upper Athabasca Valley and may extend into Montana.

It appears that both sides of the argument are enamored with the "all or nothing" school of logic. There are three possible reasons for this situation. First, there is the traditional assumption of synchronous glacial events; that is, that all glacial processes in any particular glacial period occurred concurrently. Second, there is the tendency among geologists to be insensitive to the type, quality, and particularly the scale of data needed by other disciplines. "While some geologists are satisfied with generalized overviews of regional glacial coverage, small ice-free areas, obscured by such coarse-grained perspectives, might be of great significance to biologists or archaeologists" (Fladmark 1983:14). Determining whether any potentially habitable land was present in the immediate vicinity of the Late Wisconsinan Laurentide ice sheet requires data with greater resolving power than that normally utilized in geological models of ice cover. "In these cases very precise and rigorous determinations of glacial boundaries in space and time become all important. Often such data are lacking, and evaluations of inconclusive evidence frequently reflect merely individual researchers preferences for 'maximum' or 'minimum' models of Late Wisconsinan glaciation" (Fladmark 1983:22).

Finally, there is the inability of most contemporary scientists, including geologists, to accept an inherently chaotic or "detotalizing" view of the world. A detotalizing theoretical structure for research is an alternative to the traditional totalizing framework, which "either ignores that which it cannot subsume or marginalizes it either as an anomaly or as something to be eventually incorporated at a future date" (Shanks and Tilley 1989:7) Most scientists, including those geographers and geologists involved in the ice-free corridor debate, use a totalizing framework. A chaotic environment or past reconstruction is not acceptable to those who seek a totalizing structure of order and logic. Thus ideas or evidence that do not fit neatly into the larger picture are inevitably glossed over and/or ignored.

There is a great attraction for the simple elegant answer that fits as many elements as possible together into one thematic picture. For example, Kvill (1985:199) states, "it is worth remembering that it is inadvisable to develop a model which is more complicated than necessary . . . Therefore, until there are observational data to the contrary, one should assume the simplest possible model to explain a set of observations." He further states concerning his work in the Brazeau River Valley that "this means that geomorphic and stratigraphic evidence for multiple glaciations ought not to be assumed unless there are some observations that are not explicable under the premise of a single event" (Kvill 1985:199). In other words, start out by assuming one glacial event occurred and try to fit observed evidence into this scenario. Only if evidence clearly cannot be explained as due to one event do we move to the complexity of multiple glacial events. Perhaps this seems a reasonable approach; however, it can be misleading.

In the absence of firm chronologic controls (which are lacking in the Brazeau area, and throughout most of the region under contention) it is no more correct to assume one as opposed to two or three events. It is an oversimplification to assert that one event equals simplicity. In fact, explaining all the land forms observed as a result of one glacial event requires quite a complex scenario during that one event. Contrary to some beliefs, the simplest answer is not necessarily the correct one. It is simply the simplest; and in many cases simplistic. I feel that with the complexity of the geological problems, the equivocal data and the lack of reliable chronological controls in many areas, that one simply must be open to the possibility of complicated answers.

Assumptions of simplicity and order may serve only to constrain and limit our abilities to perceive the reality. Scientists' perceptions of how things should operate are often oversimplifications and as such are prone to conflict with the real world. As just one example, there is the recent report that mountain glaciers in western Norway are advancing, an apparent contradiction to simplistic universal global warming predictions (Edmonton Journal 1990). It is time to retreat from the battlelines of limited vs. extensive or open vs. closed and examine the reality of the complex mosaic of data, incomplete, chaotic, nonsynchronous and detotalizing as it may be. Why assume the only choices are completely coalescent ice or a completely open corridor? The available data suggest several other options.

Figure 6.3 depicts my compilation from selected sources of one reasonable interpretation of the geological evidence. It is not presented as the "correct" or "only" or even my "preferred" scenario. It is simply offered as an alternative to the extremes discussed earlier. And it should be pointed out that the boundaries depicted are once again net or accumulative frontal positions and should be viewed as one possible snap shot, one moment in time in the development of "a complex region whose exact limits and

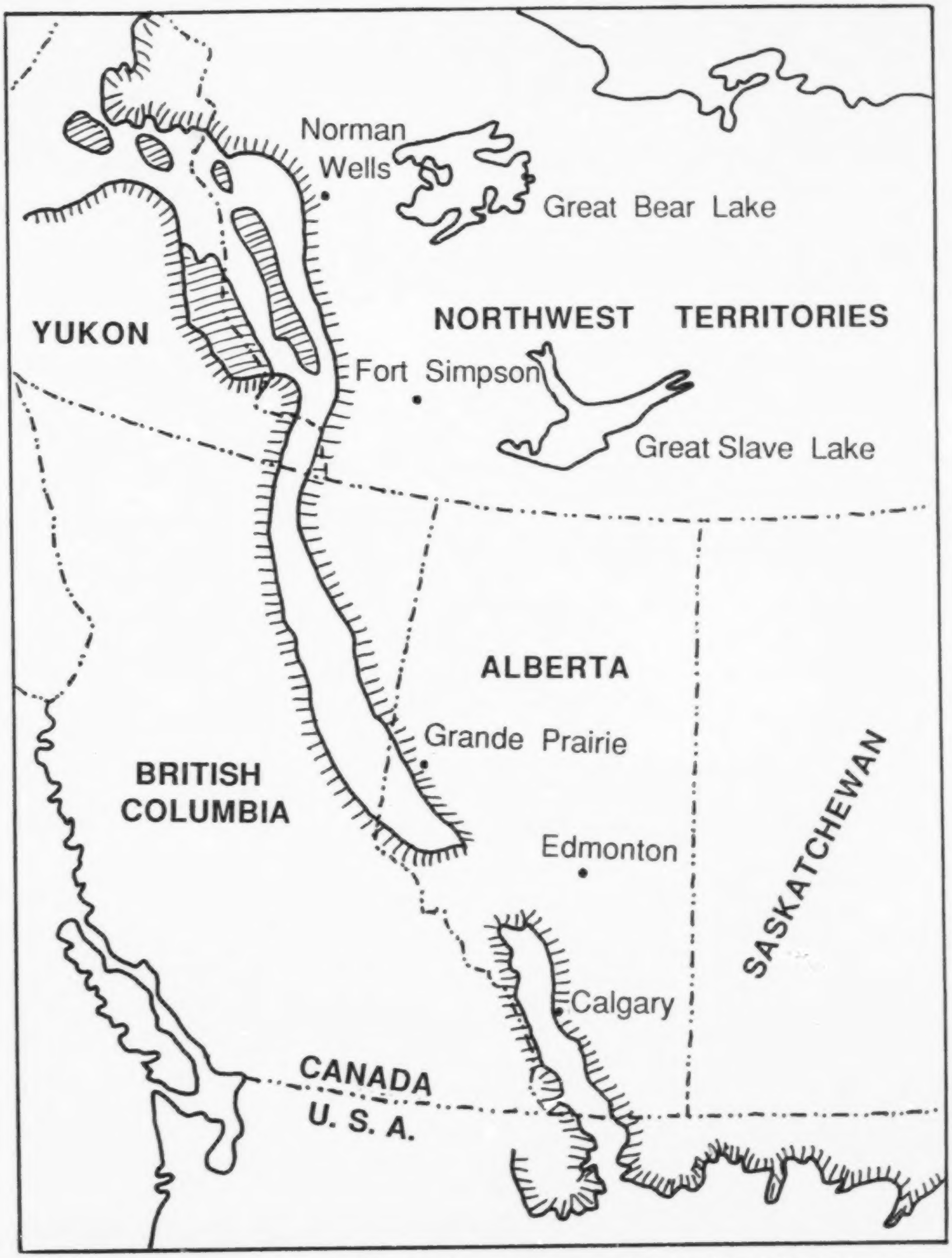
Norman Wells
Great Bear Lake
NORTHWEST TERRITORIES
YUKON
Fort Simpson
Great Slave Lake
ALBERTA
Grande Prairie
BRITISH COLUMBIA
SASKATCHEWAN
Edmonton
Calgary
CANADA
U. S. A.

Figure 6.3 Possible Late Wisconsinan Maximum Ice Limits. Adapted with modifications from Roed 1975; Stalker 1977; Boydell 1978; Mickelson et al. 1983; Kvill 1985; Carrara et al. 1986; Dyke and Prest 1987; Barnosky 1989; and Bobrowsky et al. 1990. Level of detail of information may vary between regions.

characteristics varied with time-transgressive and possibly diachronous eastern and western margins" (Fladmark 1983:28). This is an especially important consideration considering the apparent rapidity of some Late Wisconsinan glacial events.

The rationale behind the choices for borders largely follows Bobrowsky et al. (1990), except for

1) the Jasper to Red Deer area where much evidence (Roed 1975; Boydell 1978; Kvill 1985; Levson and Rutter 1988; Burns 1990), supports the contention that coalescence may have occurred in this area in Late Wisconsinan times; and

2) the far southeastern corner of Alberta near the Cypress Hills where recent work (Klassen and Vreeken 1987; Kulig, personal communication) suggests Late Wisconsinan ice reached at least to the International border. Generally, conclusive evidence for either extensive coalescent ice or restricted ice limits associated with ice-frtee areas, is lacking[1] south of the Rocky Mountain House region (Harris and Boydell 1972). Either (or neither) interpretation can be argued to be supported by the available evidence; there is no reliable basis for definitively selecting among them. Clearly this is the next region where additional field work needs to be done.

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[1] Rains et al.'s (1990) argument for coalescent ice throughout central and southern Alberta relies heavily on the questionable assumption that all ice limit indicators formed simultaneously; therefore their conclusions are open to question.

6.2 The Physical Environment of the Ice-Free Corridor

6.2.a Introduction

The last section dealt with establishing a plausible interpretation of ice front positions during the last glacial maximum, estimated as betweenca. 22,000 and 18,000 years ago [based on Burns' (1989) undertill vertebrate dates in the Edmonton and Hand Hills areas and the date of ca. 18,000 B.P. for zone ML-1 at Mitchell Lake]. This section is concerned with the environment and processes characteristic of the corridor whenever it existed. That is, the above argument aside, we know that at some point the corridor was open. More interesting than the question of existence is the question of what environmental conditions were like in the times when humans were not prevented by ice masses from occupying the area. If people could have existed in the corridor area ca. 18,000 to 16,000 years ago, they would have found themselves in essentially a periglacial environment, as climatic conditions would not have significantly improved.

6.2.b Periglacial Environments

Whatever open nonglaciated areas existed between the Late Wisconsinan Cordilleran and Laurentide ice sheets ca. 18,000 to 16,000 years ago were undoubtedly under the influence of periglacial processes. Periglacial processes are non-glacial processes occurring in a zone adjacent to glacier margins for which cold temperatures associated with the glacial period are the operant factor (Porter 1988; Jackson et al. 1982).

The clearest indication of former periglacial conditions are the many ice-wedge casts found throughout nonglaciated areas of Alaska and northwestern Canada and in a zone directly south of the continental ice sheets (Pewe 1983). Ice-wedge casts indicate that active ice wedges formed in permafrost in areas that now lack such permanently frozen ground.

"Because active ice wedges are restricted to regions where mean annual temperature is -6ºC (21.2ºF) or colder, casts of former ice wedges provide a measure of the minimum temperature conditions when they were active" (Porter 1988:4). Calculations of ocean surface and land temperatures outside glacial margins indicate a lowering of temperature of at least 5 to 13ºC with maximum temperature declines in the periglacial zones closer to the ice sheets (Mears 1981; Porter 1988).

Calculations of the lower limit of permafrost during the last glaciation (Fig. 3, Porter 1988, after Pewe 1983 Fig. 9.14) indicate that any regions north of the International Boundary (49ºN) and above approximately 900 to 1000 m in elevation would inevitably have been under the influence of periglacial conditions. This includes virtually all of any possible ice-free corridor area.

As previously mentioned, numerous indicators of permafrost and periglacial conditions are found in a band south of the ice sheets from Montana to New Jersey (Pewe 1983; Karlstrom 1986; Porter 1988; Johnson 1990). There are, however, few clear indicators in the immediate ice-free corridor area. Ice wedge casts in sands and gravels in the Edmonton area occur only below till (Westgate 1969). Thus while they may date to early in the Late Wisconsinan, they do not pertain to the portion of the full-glacial considered in this study. South of the ice-free corridor area, the Del Bonita Plateau of the Milk River ridge area of southern Alberta, long recognized to have been an unglaciated region, is mapped by Shetsen (1987) as cryoturbated eolian and fluvial deposits. Gravel pits in the Del Bonita area contain clear ice wedge casts (Brierly 1990; personal observation). Relict periglacial structures have also been observed in the Kananaskis area of southwestern Alberta (Mehew 1990) and on unglaciated parts of the

Cypress Hills nunatak, and on older tills south of the Cypress Plateau (Klassen 1990) in southeastern Alberta.

Burns (1990:64) notes the truth of "the old adage that 'absence of evidence does not constitute evidence of absence." Perhaps there are indicators of relict periglacial conditions in the corridor area that haven't been discovered yet. If the corridor was in fact open throughout the Late Wisconsinan maximum, the landscape was subjected to the necessary cold temperatures and the indications should be there, unless they were totally buried by subsequent Holocene processes, or the presence of large proglacial lakes had an ameliorating affect (cf. Brown and Pewe 1973). Referring to a comparable landscape, Pewe (1983) notes that the large reentrant (ice free area) between the Des Moines lobe in Minnesota and Iowa and the ice front in eastern Wisconsin and Illinois was a particularly favorable locality for the formation of ice wedges during Late Wisconsinan time. He credits the large number of wedges discovered in this region (more than 200 reported from the driftless area of Wisconsin alone) to be "largely a result of the vast experience of the trained observer of ice wedges and ice-wedge casts who identified them" (Pewe 1983:167).

Perhaps the case in Alberta is simply that not enough concerted effort has been made to look for such phenomena, although Kvill (1985) did unsuccessfully search the Brazeau River region. Of course, if his interpretations are correct that his study area was the site of the coalescence of Cordilleran and Laurentide Late Wisconsinan ice, this fact would explain the lack of periglacial features in that region. Lack of exposures in the Foothills and Plains area also may contribute to the paucity of discovered periglacial features.

As already mentioned in Chapter 5, climatic evidence indicates cold, dry, and windy conditions in the northwest United States and northern Plains during full-glacial times (Wright 1991). Evidence from climatic modeling suggests that the westerly jet stream split into two streams that were directed north and south of the ice sheets. The southern stream was deflected too far south to bring moisture to the northern Plains, instead delivering it to the southwest United States and the Great Basin (Kutzbach and Wright 1986; Manabe and Broccoli 1985).

Reconstructed paleo-equilibrium line altitudes of Late Wisconsinan glaciers in Montana indicate roughly a 25 cm decrease in precipitation in general across Montana, with as much as a 50 cm decrease in precipitation in some areas (Locke 1990). It is likely that decreases in precipitation in any ice-free areas north of the border would have been comparably low (or lower).

Additionally, not only was moisture unavailable from the main source of moist air today, resulting in highly continental conditions, but the anticyclonal winds coming off the ice resulted in persistent dry and cold easterly surface winds close to the periphery of the Laurentide ice sheet, and southeasterly winds blowing up the ice-free corridor (MacDonald 1987). In addition there were likely katabatic winds off the ice, which were perhaps enhanced by cold Arctic air being funnelled down the corridor between the ice sheets (Bryson and Wendland 1967; Lamb and Woodroffe 1970; Wright 1991).

Many of the winds predicted by climatic modeling are supported by paleowind direction evidence from sand dunes throughout the northern Plains (Odynsky 1958; David 1981). Also, the existence of the dunes themselves suggests arid conditions. Under moist conditions vegetation cover would likely stabilize the dunes or perhaps prevent them from forming in the first place. Dune fields of the magnitude of the Nebraska Sandhills (formed during the Late Wisconsinan) currently form only in semi-desert regions where annual precipitation is but 15 to 30% of modern values (Wright 1987: Wells 1983). The deposition of up to 3 meters of loess on top of the Cypress Hills also indicates the existence of arid, windy conditions in full-glacial and/or late-glacial times (Hardy 1971).

Thus the periglacial environment of any area near the ice sheets, and in particular an ice-free corridor between them would have been characterized by cold, dry, windy conditions, where sand-wedges and/or ice-wedges and patterned ground and loess deposition occurred. Much of the corridor "would have been occupied by raw morainal deposits, meltwater pondages, stagnant and buried ice blocks and rugged mountain slopes . . . Constant cold wind, dust, bare rock, lakes, permafrost and ice were probably dominant environmental features" (Fladmark 1983:29). It would have been a formidable environment, particularly in the immediate vicinity of the ice where the landscape would have been "harsh, raw and primitive. Anyone who has clambered over loose piles of rock rubble and skirted meltwater streams and ponds to reach the steep crevassed and dripping front of even a small modern glacier probably needs no convincing that massive Pleistocene frontal areas must have been unpleasant and oppressive" (Fladmark 1983:28).

As shown on the maps of possible ice-free corridor boundaries (Figures 6.1 to 6.3), large proglacial lakes also would have been a prominent part of the environment. Besides being biologically sterile (Schweger, personal communication), these "cold, berg-laden, [lakes] with unstable shorelines and fluctuating levels . . . could only have been disadvantageous to any human inhabitants" (Fladmark 1983:29). In some areas it is likely that they filled the region between the ice sheets, thus eliminating any open corridor at that locality in warmer seasons. Yet, "since it is likely that all lakes froze solidly in winter, they probably would not have seriously hampered mammalian dispersals" (Fladmark 1983:29). Proglacial lakes of course are not a result of strictly periglacial processes, being formed in direct contact with glacial ice damming the normal drainage of a region. They are, however, often overlooked in discussions focusing on ice boundaries, when in fact they were a significant part of the glacial/periglacial landscape in Alberta.

6.2.c Causes and Timing of Deglaciation

At one level of explanation it can be said that the Late Wisconsinan ice sheets melted because the climate changed.

> The ultimate cause of deglaciation is now widely acknowledged to be the orbital forcing proposed by Milankovitch (1941), involving the three cycles of earth/sun geometry that control the distribution of solar radiation on the earth: the tilt (obliquity) of the earth's axis, the eccentricity of the earth's orbit around the sun, and the precession of the equinoxes (Ruddiman and Wright 1987:1).

Variations in obliquity, precession, and eccentricity cause significant changes in the spatial and temporal distribution of radiation received on the earth's surface, and result in external forcing of the earth's climate. The contemporary interpretation of the Milankovitch theory "states that cyclic variations in summer insolation at specific Northern Hemisphere latitudes trigger the advance and retreat of Pleistocene ice sheets spanning these latitudes" (Hughes 1987:183). The relationship between the Milankovitch variations and glacial/interglacial cycles has been well documented by correlation with isotope records from deep sea cores. Analysis of the isotopic composition of deep sea cores from the ocean has revealed clear peaks corresponding to the Milankovitch cycles at approximately 23,000, 42,000, and 100,000 years ago (Broecker et al. 1968; Hays et al. 1976).

Examination of the "insolation signatures" at 60°N over the past 200,000 years (Bradley 1985:Fig. 2.21) reveals that the deviations change gradually, as expected. However the actual pattern of glaciation cycles reveals that although "glaciation was prolonged and unsteady . . . deglaciation was swift and sure" (Hughes 1987:183). If the changes in insolation are gradual why is deglaciation so sudden? Hays et al. (1976) suggested that

> nonlinear responses in the climate system amplify the effects of direct insolation forcing in such a way as to give the observed ice-sheet response; one nonlinearity they proposed was that ice sheets decay faster than they grow (Ruddiman and Wright 1987:5).

Nonlinear responses may relate to the intransitive or almost-intransitive nature of the global climatic system.

Traditionally it has been assumed that climate acted as a transitive system, that is, one in which "for a constant set of forcing functions, a single steady climate results" (Barry 1982:2). In other words, a unique solution exists. This is a deterministic point of view. There is, however, much evidence to contradict the viewpoint that climatic causes are deterministic and transitive. For example, the existence of feedbacks "suggests that the climate system does not respond uniquely to a unique forcing and may be intransitive or almost-intransitive" (Tzvi Gal-Chen 1982:218). An intransitive system is one that has "two or more sets of long-term statistics, each of which has a greater than zero probability of resulting from randomly chosen initial conditions" (Lorenz 1968:2). In other words, more than one equilibrium state can result from the same initial forcing conditions or boundary conditions (Fig. 6.4).

An almost-intransitive system is one that is transitive over the long term but intransitive over the short run; even for constant forcing, the system is oscillatory. It "may spend some time at state B, then move rapidly to state A, and so forth. The climate exhibited by such a system would thus consist of several quasi-stable states, together with periods of transition between them" (Tzvi Gal-Chan 1982:109). This is similar to the concept of dynamic metastable equilibrium (Fig.6.5). Long term dynamic equilibrium conditions or trends are separated by a threshold. When certain conditions or values reach a threshold, the equilibrium moves to a new level (Butzer 1982). The concepts of almost-intransitivity or dynamic metastable equilibrium provide a possible explanation for the abrupt changes in climate that resulted in rapid ice stagnation and decay.

> The deglacial scene was dynamic on the time scale of a few thousand years. As summer radiation increased, the ice sheet ceased to advance, except locally. Wastage then set in and accelerated as the summer radiation increased further, and the various feedback mechanisms affecting the ice sheet . . . resulted in instabilities of the ice margin (Ruddiman and Wright 1987:9).

The rapid transition from glacial to nonglacial climates provides a plausible mechanism for the formation of the extensive areas of dead or stagnant ice terrain that were the primary characteristic of the deglaciation environments.

Although Ruddiman and McIntyre (1981) note that isotopic measurements in cores in the Gulf of Mexico show large influxes of meltwater beginning around 17,000 years ago, when summer insolation values were greater than today, it is not easy to pinpoint when deglaciation

Figure 6.4 Transitive vs. Intransitive Systems. After Gal-Chen (1982:210). Reproduced with permission from Academic Press.

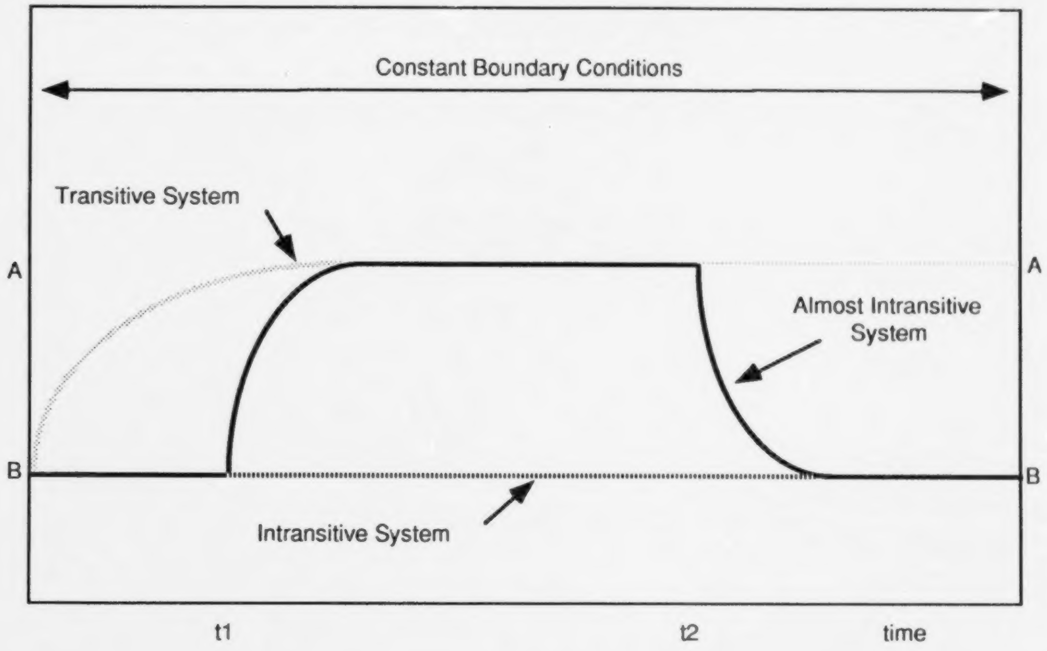
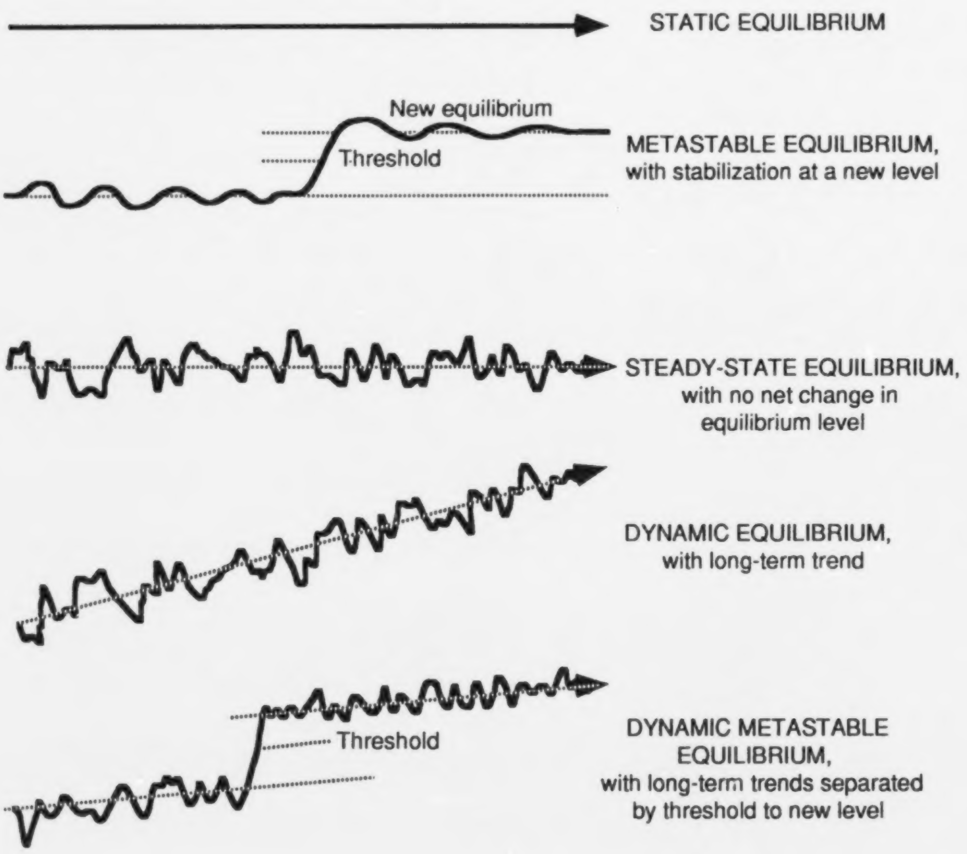

Constant Boundary Conditions
Transitive System
A
A
Almost Intransitive System
B
B
Intransitive System
t1
t2
time

Figure 6.5 Equilibrium Types. After Burzer (1982:Figure 2-3). Reproduced with permission from Cambridge University Press Rights and Permissions Department.


STATIC EQUILIBRIUM
New equilibrium
Threshold
METASTABLE EQUILIBRIUM, with stabilization at a new level
STEADY-STATE EQUILIBRIUM, with no net change in equilibrium level
DYNAMIC EQUILIBRIUM, with long-term trend
Threshold
DYNAMIC METASTABLE EQUILIBRIUM, with long-term trends separated by threshold to new level

began. The commonly accepted date for the Late Wisconsinan glacial maximum is 18,000 B.P., both in terms of extent and climatic conditions. By definition, a glacial maximum is necessarily at or near the end of a period of glacial climate (Bryson and Wendlend 1967). Thus one possible interpretation is that deglaciation would have begun immediately after 18,000 years B.P.

There is, however, little physical evidence to support this interpretation. Much of the evidence that does exist for timing of deglaciation comes from different lines of evidence that do not always seem to agree. Relying purely on the retreat of the Laurentide ice front results in estimates of ca. 12,000 to 13,500 for deglaciation in Alberta (Matthewes 1980; Klassen and Vreeken 1987). Yet, evidence from other sources indicates deglaciation may have begun as early as 17,000 to 16,000 years ago (Ruddiman and McIntyre 1981; Ruddiman 1987). The apparent contradiction can be reconciled as it appears that areal retreat of the southwestern portion of the Laurentide ice sheet (that part located largely in Alberta and Saskatchewan) began only after the ice had thinned substantially (Christiansen 1979).

The record shows that the influx of meltwater accelerated to a maximum by 13,500 yr B.P. Several sources of evidence indicate extensive ice retreat and the beginning of evidence of non-glacial times in the period 14,000 to 12,000 years ago (cf. Hoganson and Ashworth 1992). Calculation of global ice volume changes indicated by changing ^{16}O:^{18}O isotope ratio levels in the Camp Century ocean cores show 50% of the ice sheets had melted by 13,000 years ago, when ice margins had retreated less than 300 km from maximum positions (Dansgaard et al. 1971; Teller 1987). As the ice sheets still occupied 75 to 80% of their full-glacial aerial extent, but had decreased by 50% in volume, it is clear that a significant thinning had occurred (Ruddiman and McIntyre 1981). It is only after 14,000 years ago that significant areal retreat is apparent. Because of this it is difficult to discern the character of the early stages of deglaciation.

In Chapter 5 the late-glacial period, ca. 16,000 to 12,000 years B.P., was defined as the period and events associated with transitional glacial conditions, when "glaciers were still widespread and while occasionally expanding were in general receding" (Ritchie 1987:6), and the post-glacial, ca., 12,000 to 10,000 years B.P. as the period and events following the disappearance of glacial ice. Although, as discussed earlier, there is some subjectivity in these definitions and the particular boundaries picked for the time periods, these periods correspond fairly well with the time period of deglaciation, which surely began by 16,000 years B.P., and was essentially complete in Alberta by approximately 10,000 years B.P.

When discussing environments of deglaciation in Alberta it is difficult to restrict oneself to particular time periods, as the effects and circumstances of deglaciation were to a large extent time-transgressive events following the volumetric and areal retreat of the Laurentide ice sheet to the northeast. Because of this, the nature of the environment in Alberta during deglaciation will be discussed in general processual terms.

It also should be noted that the deglaciation environments of Alberta should be of particular interest to archaeologists as it is these conditions that early inhabitants were most likely to have encountered. While it is still conjecture whether humans entered the New World during or prior to Late Wisconsinan times, it is no longer speculation to state that humans were present in Alberta during deglaciation of the ice sheets. There is clear evidence of human presence ca. 11,000 B.P. (Fedje et al. 1985) and one can speculate that humans were present at least one thousand years earlier.

The shift in focus among archaeologists in Alberta from a Late Wisconsinan maximum ice-free corridor to interest in the period of deglaciation of the ice sheets, and in fact the rejection of the phrase "ice-free corridor" altogether has already been mentioned. Clearly an understanding of deglaciation environments of Alberta is important to archaeology.

6.2.d Processes of Deglaciation

6.2.d.1 Introduction

The previous section outlined a mechanism for abrupt climate change and the resulting stagnation of continental ice. The rapidity of the climate change helps explain the large extent of stagnant ice in western Canada. The ice was abruptly cut off from its source area; left stranded on high ground throughout the prairies. This development would have been especially likely to happen if as has been proposed (cf. Ruddiman and McIntyre 1981), the ice was already substantially thinned by ablation. As studies of modern day stagnant glaciers suggest, although climatic amelioration is the fundamental cause of stagnation, additional factors may be necessary (Sharp 1951). Extensive thinning is one such factor; i.e., "stagnant ice is usually a product of glacial thinning and its presence is evidence that thinning has occurred" (Flint 1942:120). Dead or stagnant ice is that which no longer receives a supply from an accumulation area, but may still survive for an extensive period on its own mass (Embleton and King 1975).

6.2.d.2 Rates of Deglaciation

The nature of stagnant ice makes determining the rates of deglaciation especially difficult. In eastern North America, which lacks significant areas of stagnant ice terrain, retreating ice front positions tend to be clearly marked by successive terminal moraines. The west however, lacks a clear record of deglaciation events. Several workers (e.g., St. Onge 1972; Matthewes 1980; Christiansen 1979) have mapped deglaciation ice front positions in Alberta and Saskatchewan based on locations of proglacial lakes ponded at the western border of the Laurentide ice sheet. The assumption is that these lakes reflect retreat of the ice front. This interpretation implies that land west of the pondages is by definition ice-free. The complicating issue can be put as "When is an ice front really an ice front?" It is likely that the boundaries mapped by the above researchers are not ice fronts at all in the classic sense of an active retreating mass of ice. It is also likely that it is not possible to determine accurate ice frontal positions in regions of stagnant ice.

Study of ice-dammed lakes in Scandinavia reveals that generally ice has to be active and/or very thick in order to dam lakes. Stagnant ice can only dam relatively small ephemeral waters because it lacks an adequate horizontal pressure component. Lundquist (1972:28) states, "an ice-lake (or ice-dammed lake) may be defined as a body of stagnant water, the existence of which depends on damming by ice . . . The condition for the formation of an ice lake is a) a land surface sloping towards the damming ice, and b) an ice body compact enough to keep the water dammed."

If it is unlikely that stagnant ice is capable of damming a drainage system, perhaps the maps of retreating ice front positions are chronicling the retreat of thick ice or ice that is not yet both climatically and dynamically dead. Embleton and King (1975) define climatically dead ice as that which no longer receives a supply from an accumulation area, whereas dynamically dead ice is that which has also ceased to move. Ice that is climatically dead but not dynamically dead may retain the ability to dam lakes; i.e., movement contributes the necessary horizontal pressure.

It is not surprising that a belt of completely dead ice would surround a core of ice that is only climatically dead, nor that the degree of "deadness" develops time-transgressively from the western borders to the interior of the remaining ice sheet. Those areas closest to the source of accumulation would likely be the last to become both climatically and dynamically dead. The time-transgressive nature of the transition from active to dead ice precludes any assumption of uniform environments across Alberta at any one time. Instead there would be great heterogeneity, with "the aspect of the morainal surface at any moment [being] a function of the time elapsed since the ice became stagnant" (Driscoll 1980:31).

Probably one shouldn't even think in terms of ice retreat when discussing deglaciation in western Canada but instead focus on downwasting and associated processes. If, as proposed above, supposed ice retreat boundaries indicate degree of "deadness" of stagnant ice, then extensive areas of stagnant ice were draped with lacustrine sediment as the active/dead transition line moved to the northeast. This draping with lacustrine sediment has important ramifications for the rate of down wasting of the residual ice mass.

There is much uncertainty regarding how long residual stagnant ice could last under modern climatic conditions. Current stagnant ice and permafrost — which is thermally analogous to buried glacial ice (Florin and Wright 1969) — that remains frozen in equilibrium with the present interglacial climate, occurs only at high latitudes and/or altitudes. The key to the continued presence of ice appears to lie in the nature of the debris cover. Observations of modern glaciers reveal that while a thin layer of debris hastens melting of ice, thicker layers shield the ice, slowing or stopping its melting (Ostrem 1965; Jewtuchowiz 1968; Russel 1893; Clayton 1964; Post and Streveler 1976). Ostrem's (1959) classic study of the effect of debris cover on ablation on a glacier in Sweden concluded that the rate of ice melting decreased when the debris cover was more than 0.5 cm thick. As the thickness of the cover increased, the rate of ablation decreased until by the time cover was 30 cm thick ablation was almost nonexistent (Fig. 6.6). A recent study using comparisons between the debris-covered Dome Glacier and the relatively debris-free Athabasca Glacier in Jasper National Park, Alberta, reveals an almost identical relationship (Mattson 1990). The main difference is that decreases in ablation on the Dome Glacier do not occur until the debris cover is greater than 3 cm. The greater amount of debris necessary to act as a buffer between the glacier and climate may be due to the lower latitude and consequent greater insolation and temperatures received.

There have been some objections that continental ice sheets would not have sufficient debris to insulate the ice (Gravenor and Kupsch 1959). Studies of debris-covered stagnant ice have all been done on valley glaciers, which get much of their debris from valley walls. But, as already mentioned, it is likely that extensive areas of stagnant ice were covered by loess, as well as lake deposits and their associated beach and deltaic deposits. As St. Onge (1972:6) states, "hummocky moraines composed of silt and sand that probably originated as lacustrine and/or fluvial deposits on anchored stagnant ice are commonly found in Alberta." Additionally, unlike many other glacial circumstances, the rivers in Alberta did not exit the Laurentide ice mass, carrying away outwash; instead rivers primarily flowed toward the ice mass, carrying a substantial component of debris.

Figure 6.6 has been removed because of copyright restrictions. It was a copy of G. Ostrem's (1959) graph illustrating ablation rates of debris covered glacial ice.

In any case strictly exterior or additional debris being added to the surface of the continental glacier is not really necessary. A study of the Wolf Creek Glacier in the Yukon showed that "fully 90% of the superglacial debris is derived from an englacial source. A mantle averaging two feet thick has developed by ablation of ice containing but a fraction of 1 per cent debris" (Sharp 1949:290). This glacier is circumstantially and environmentally a good analogy for the western region of the continental ice sheets as it is on the interior side of a high mountain range with a continental, almost semi-arid climate, characterized by clear skies and extensive summer sunshine (Sharp 1949). Using the rates of surficial accumulation of englacial debris observed at Wolf Creek Glacier (i.e., 2 feet of debris derived from some 500 feet of downwasted ice) results in an estimate of approximately one meter of superglacial debris from purely englacial sources by 13,000 yr B.P, and up to two meters by 10,000 yr B.P. Thus even without external additions, enough debris was available to insulate the residual Pleistocene ice. In any case, it is most likely that the debris cover on the western margins of the Laurentide ice sheet came from both englacial and proglacial sources.

Estimates of the rate of melting of the Pleistocene ice sheets are problematic. The difficulty lies in the number of variables that are unknown. Keeping in mind the limitations, limited "guesstimates" are possible. Various estimates of Laurentide ice sheet thickness have been proposed over the years, generally ranging from approximately 600 to 5000 meters thick (cf. Andrews 1973; Matthewes 1974). More recent estimates lean toward the thinner side of the spectrum as the single ice dome hypothesis is being replaced by the multiple ice center, therefore thinner ice sheet, scenario (cf. Beget 1987). Obviously maximum ice thickness may be impossible to reconstruct definitively. Minimum ice thickness, however, may be more accessible. Rains et al. (1990) make a convincing argument that the Laurentide ice sheet had to have been at least 1400 m thick over cantral Alberta at glacial maximum. If we accept estimates that half the ice mass had melted by 13,000 years ago (Ruddiman and McIntyre 1981: Christiansen 1979), then approximately 700 m of ice topped by debris from various sources remained at 13,000 yr B.P.

One of the best dated examples of rates of melting of stagnant debris-covered ice comes from Lituya Bay in Alaska where a neoglacial ice advance subsequently stagnated and is now covered by more than 60 m of debris topped by coniferous forest (Post and Streveler 1976). The rate of melting of the stagnant Lituya Bay Glacier is estimated to average 20 cm a year (Post and Streveler 1976). The mild marine climate is not strictly comparable to the conditions encountered by stagnant ice in postglacial Alberta, i.e., cloud and moisture versus sunshine and humidity. However if the 20 cm a year rate of melting is applied to the presumed 700 m of remaining Laurentide ice, an estimate of approximately 3500 years required for complete melting of the ice results; or in other words, it took from 13,000 to 9,500 yr B.P. for the debris-laden stagnant ice throughout Alberta, Saskatchewan, and North Dakota to melt completely.

Support for this estimate comes from the Leslieville bison site located approximately 30 km northeast of Rocky Mountain House in a hummock in an area of dead ice moraine in Sylvan Lake (Laurentide) till (Boydell 1978). The site is characterized by the stratigraphic complexity typical of collapse topography in the last stages of melting of stagnant ice (Clayton and Moran 1974). Dates on bison bone of 9,670 +/- 140, and gastropods, of 10,250 +/- 165 from the site were interpreted by Boydell (1978) as evidence for a delayed retreat of Late Wisconsinan Laurentide ice in the area.

If interpreted as dating active ice, the dates are confusing and inconsistent with other lines of evidence, which suggest most of Alberta had been deglaciated by this time. It is, however, quite likely that the dates are correct as reported and the mistake lies in interpreting them as dating active ice. All the evidence supports the alternate conclusion that the ice in question was likely deeply buried stagnant ice that could in fact have lasted in the Rocky Mountain House area until circa 10,000 to 9,600 years ago.

There are numerous other examples of ice-cored and dead ice, both Pleistocene and modern, lasting 1,000 to 3,500 years after stagnation (Porter and Carson 1971). Emerson (1977), for example, reported dates of 10,900 +/- 190, 10,880 +/- 155, and 9,050 +/- 150 on freshwater mollusca from superglacial lacustrine sediments in the Cooking Lake Moraine east of Edmonton, Alberta. He interprets these dates as indicating that Late Wisconsinan Laurentide ice "stagnated in the area for approximately 2,000 years before it and the superglacial lakes disappeared" (Emerson 1977:101), i.e., that the mollusca lived in small shallow lakes atop the debris-covered ice sheet.

The approximately 600 year difference between the samples from the Leslieville bison site and the 2,000 year difference among the samples from the Cooking Lake moraine is not problematic because first, the dates from Leslieville are from different materials, and in any case, variable dates are common from stagnant ice areas and may themselves serve as a clue for the presence of such stratigraphy. Florin and Wright (1969), for example, cite dates from an area of dead ice terrain ranging from 400 to 3,000 years after active ice retreat.

The fact that few lake basins in Alberta have basal dates greater than

10,000 to 11,000 years ago has often been interpreted as indicating continued presence of active ice that prevented lake sedimentation until after ice retreat. On the contrary, it is likely that due to the slow melting of ice insulated under a blanket of superglacial debris or glacial, fluvial, or lacustrine origin, "many post-glacial depressions came into existence long after the ice stagnated, and active glaciation occurred hundreds or thousands of years earlier than is often assumed from dates at the bottoms of these depressions" (Clayton and Moran 1982:58). Basal lake dates from areas of dead ice terrain most likely indicate the time of complete meltout of stagnant ice, when basins intersected and were walled by the ground surface; all earlier ice-walled lakes having been destroyed by melting of the surrounding ice.

6.2.d.3 Formation Processes of Ablation Moraine

Clearly, stagnant ice may have lasted well into Holocene times and covered extensive areas of Alberta, Saskatchewan, and North Dakota, as indicated by the presence of hummocky moraine deposits and the absence of evidence for permafrost. These deposits are alternatively referred to as ablation, disintegration, or dead ice moraine (cf. Gravenor and Kupsch 1959), but always refer to material associated with disintegration of stagnant ice as material accumulated through downwasting of the ice surface (Embleton and King 1975). The characteristic morphology of ablation moraine contains such features as knobs and kettles, prairie mounds, moraine plateaus, lacustrine plains, dead ice hollows, and doughnuts or rims, along with kames and eskers and numerous lakes (Embleton and King 1975; Gravenor and Kupsch 1959; Winters 1961; Hoppe 1952).

The two primary theories regarding the mode of formation of these features are the "let down" theory, and the "ice-pressed" theory. The let down theory argues that as the ice gradually ablated, downwasting instead of melting back, incorporated debris accumulated on top. The formation and existence of ablation till has already been mentioned. The key to the formation of classic hummocky moraine lies in differential melting caused by a heterogeneous and irregularly distributed till surface. These irregularities concern variations in insulating ability of the superglacial sediment, which may be caused either by variations in thickness, the effects of which were discussed earlier, or by grain size characteristics of the till, i.e., finer grained sediment insulates better than coarse grained (Nikiforoff 1928; Sharp 1949). Once differential melting has occurred, topographic irregularities on the ice promote mass movement and continued nonuniform distribution of the ablation till cover (Clayton and Moran 1974).

> Ice that has thinner superglacial sediment and so is less well insulated, melts faster to form depressions. Areas of thicker superglacial sediment are higher and mudflows occur when the slopes become steep enough. These mudflows tend to fill the depressions, which then have thicker superglacial sediment than the high areas; the ice under them melts more slowly and they then become the high areas (Clayton and Moran 1974:107).

The result is a continual reversal or inversion of topography with flow tills and various lacustrine facies in a complex sequence of tills and bedded sediments (Jewtuchowiz 1968). Sugden and John (1976:256) note the "extremely confused topography and rapid transformations of the surface which take place" as the ice melts. At the Wolf Creek Glacier in the Yukon, Sharp (1949) estimated that decades may be necessary for a complete inversion of the surficial debris. Clayton and Moran (1974:107) explain how

> as the inversion of topography on the glacier approaches the final phase of its last cycle, the bottoms of the sinkholes melt

> through to solid ground, resulting in circular holes in the glacier. Material flowing down the sides of these holes may completely fill in the hole, resulting in a hill of material occupying the position of the former sinkhole when all of the ice finally melted; . . . if the amount of material flowing into the hole is not enough to completely fill it the material forms a doughnut-shaped ridge at the base of the sides of the hole.

The ice-pressed explanation for the formation of dead ice moraine is that features are a result of saturated basal till being pushed into basal crevasses and openings by pressure from the ice. Stalker (1960) thought this process was necessary to explain some types of forms. The first explanation above, i.e., the let down theory, is the more universally accepted and supported by evidence. As Clayton and Moran (1974) point out, the maximum diameter of primary hummocks in collapse topography is approximately 200 m, as is the diameter of circular disintegration ridges in dead ice moraine, and the diameter of primary sinkholes on the modern Martin River Glacier in the Yukon. As such, they feel this "confirms the interpretation that hummocks and circular disintegration ridges form in sinkholes and that 'morainic topography' is the result of superglacial sediment" (Clayton and Moran 1974:108).

6.2.d.4 Glacial Karst Topography

The previous section served to establish a causal relationship between stagnating ice and the resulting dead ice terrain ubiquitous in large areas of the northern Plains, i.e., that the "wasting of stagnant ice leaves an accumulation of debris reproducing on a reduced scale the irregular topography of the stagnant ice and having the constitution of the superglacial mantle" (Sharp 1949:290). Once it is established that near simultaneous ice stagnation due to climatic amelioration circa 18,000 years ago had as its result extensive dead ice terrain circa 10,000 years ago, the focus can shift to the operant processes during those intervening 8,000 years.

The processes inherent in the downwasting of stagnant debris-laden ice briefly described above have been compared to the processes characteristic of karst topography. The analogy is compelling and informative to an appreciation of both the operant processes and appearance of the resulting "glacial karst topography" (Sugden and John 1976). The primary similarity noted is that of morphology. Common glacial karst features include ice sink-holes, tunnels, caves, sinking streams, large springs, and residual "soils" or ablation till (Clayton 1964).

The glacial karst cycle is essentially the same as the limestone karst cycle, although on glaciers the process involved is melting rather than solution, and ablation till is the glacial karst equivalent of residual soils. Both ablation till and the residual soils of limestone karst origin can be seen as nonsoluble impurities in the dissolved matrix, whether rock or ice, that increase in thickness as the cycle progresses (Embleton and King 1975).

Clayton (1964) described three stages of the glacial karst cycle as seen on the stagnant ice of the Martin River Glacier. In the "Youth" stage, the ice may still be characterized as active. The surface of the ice is exposed, with till accumulating only in medial moraines. The exposed ice surface may lose some volume directly to the atmosphere through the process of sublimation, particularly in areas characterized by arid conditions. Due to the limited ablation till, little or no vegetation is present. Drainage is primarily by surface overflow and no lakes are evident, although shaft-like sink holes may occur (Clayton 1964). The youngest moraines of the stagnant Klutan Glacier in the Yukon provide an example of this first stage in the glacial karst cycle. Moraine K-1 lacks plant growth, presumably due to surface instability, whereas *Crepis nana* grows on moraine K-2 in unaltered coarse gravel and sand (Birks 1980). Perhaps this stage may be analagous to the stagnant Laurentide ice in the vicinity of Mitchell and Strubel Lakes during Zone ML-1 approximately 18,000 to 16,000 years ago.

The next stage of the glacial karst cycle, termed "Maturity" by Clayton (1964), is characterized by slightly active to stagnant ice, which has acquired an ablation till cover ranging from a few centimeters to a meter thick. This cover is fairly unstable, continually affected by the processes of topographic inversion discussed above. With a minimum amount of superglacial ablation till, a few plants are present. However, once the debris layer is 30 to 45 cm thick, vegetation increases and herbaceous pioneers are joined by various shrub vegetation (Clayton 1964; Sharp 1958).

The drainage of mature glacial karst is largely subsurface, with extensive englacial channels (Watson 1980), which may exit the stagnant ice mass with great force (Russel 1893). Funnel-shaped sink holes and tunnels occur with lakes commonly found in the sink holes. At this stage in the cycle any lakes present tend to be cold, silt-laden and barren. In addition, they are characteristically temporary, generally not lasting long enough to achieve a stable limnology (Whiteside et al. 1980; Bradbury and Whiteside 1980).

The mature stage may represent the condition of the residual stagnant Laurentide ice in the vicinity of Mitchell and Strubel Lakes during Zone ML-2 circa 16,000 to 12,000 years ago. In the transition from "Maturity" to "Old Age," as the debris layer increases in thickness to 1 to 1.5 m thick, it becomes more stable and vegetation increases. It is likely at this point that, except for the walls of sinkhole depressions, exposed ice is rare and vegetation obscures much of the surface (Reid 1970).

The final stage of the glacial karst cycle, termed "Old Age" by Clayton

(1964), is characterized by completely stagnant ice covered with a relatively stable 1 1/2 to 3 meter thick or greater mantle of ablation till that commonly supports conifer forest vegetation. The drainage is becoming surface again as the ice disappears. Lakes have clear water and stable slopes and may support freshwater plants although there is little evidence of animal life (Clayton 1964; Whiteside et al. 1980). This is the stage when final melting of the residual stagnant ice mass eventually occurs, with consequent intersection of the underlying bedrock by lakes, streams, etc., resulting in a relatively stable ecosystem characterized by extensive dead ice moraine. This stage may characterize the condition of any residual ice in the vicinity of Mitchell and Strubel Lakes during Zone ML-3 circa 12,000 to 10,000 years ago.

As alluded to in some of the above examples, glacial karst topography has been observed currently forming on existent glaciers in Alaska and the Yukon, as well as stagnant portions of glaciers in Greenland, Europe, and New Zealand. An additional modern analogy for the melting of stagnant glacial ice is the thermokarst topography found in areas of permafrost, (permanently frozen ground). As mentioned earlier, permafrost is the thermal equivalent of buried glacial ice. Thermokarst is "the process of melting of the ground surface and the formation of depressions" (Czudek and Demek 1970:103). It is caused by a disruption of the thermal equilibrium of permafrost due to either climatic or local reasons. The thermokarst process is not strictly analogous to either glacial or true karst, but there are similarities in the formation of depressions, the widespread subterranean drainage (Hopkins 1949), and the resulting "drunken" or tilted forests on the subsiding surface (Czudek and Demek 1970; Post and Streveler 1976).

Thermokarst is also interesting simply because, unlike the glacial karst of modern stagnant glaciers, it occurs in inhabited areas; and consequently may have a more direct impact on people. Large thermokarst depressions, called "alas," may form within a human generation (Czudek and Demek 1970), and have been observed by inhabitants of permafrost areas, particularly in Siberia, for over 100 years (Nikiforoff 1928).

6.2.d.5 The Chaos Factor

Whether the analogy for the melting of stagnant Pleistocene ice masses comes from modern glaciers or the thermokarst of permafrost areas, clearly the overwhelming characteristic was chaos, with continual reversal of topography, rapid transformation of the surface as the ice melts, and collapse of englacial caverns. The chaos factor, as it may be called, is referred to repeatedly by various authors. Sharp (1951:108) refers to the "chaotic superglacial topography, consisting of short stream valleys, closed depressions, and debris mantled knobs and ridges" along with arches and englacial caverns, passages and tunnels on the Wolf Creek Glacier in the Yukon. Hartshorn (1952:1260) comments that on the stagnant portion of the Malaspina Glacier in Alaska, "superglacial features will come into existence and be destroyed many times in the seemingly chaotic lowering and reversal of topography during downwastage."

Reid (1970:262) describes the situation on the Martin River Glacier in the Yukon where

> differential ablation . . . increases the intensity of mass movement of the superglacial drift and vegetation, causing large masses of alders and willows to topple and expose their roots. Broken masses of dead branches and roots dumped haphazardly over the surface add to the chaotic appearance.

In addition, he reports the "continuous roar of superglacial debris sliding and tumbling into Miller Lake . . . [and] sudden fluctuations in lake level and emergence of ice masses from the lake bottom" (Reid 1970:262), of what he feels must be an ice-bottomed lake.

Post and Streveler (1976) describe a tilted forest on the stagnant remains of the Lituya Bay Glacier in Alaska where leaning trees exhibit curved trunks and the forest is characterized by large pits and slump areas where melting is causing forest collapse into steep-sided depressions. On the Klutan Glacier in the Yukon, Wright (1980) notes that even on the oldest moraines where forest cover has stabilized the surface, collapses do occasionally occur, abruptly forming lake depressions with unstable slopes. Finally, Stephens (1969), discussing yet another example of glacial karst on the Kushtaka Glacier in Alaska, argues that a glacial karst environment is essentially an ecosystem in a continual process of being destroyed by the melting of the underlying ice. Therefore, we might say that the primary process of deglaciation was a gradual, yet chaotic destruction of the stagnant ice ecosystem.

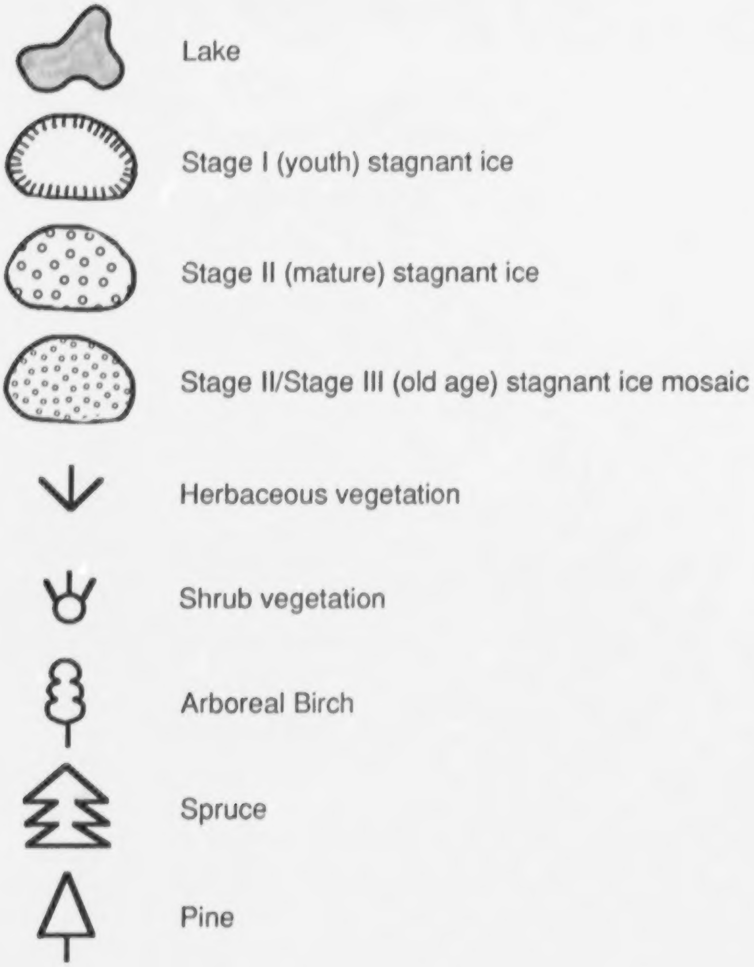
One final note on the chaotic nature of deglaciation processes and the resulting environment is that it presents a nightmare for archaeologists. Whatever time marks the moment at which the environment was suitable for human occupation, any such occupations occurring prior to the final meltout of stagnant ice circa 11,000 to 10,000 years ago (and there surely were some) were more likely than not to have been disturbed, overturned and ultimately deeply buried. Even if such deeply buried sites were to be eventually discovered, contextual evaluation and meaningful analysis will be exceedingly difficult.

6.2.e Paleogeography of Deglaciation

As outlined above, deglaciation environments are structured by the processes of the glacial karst cycle. The estimated effects of these processes on Albertan landscapes are reconstructed for ca. 18,000 yr B.P. and at 1,000 year intervals from 14,000 to 10,000 yr B.P. (Figs. 6.7 to 6.12). Maps are lacking for the period between 18,000 and 14,000 years ago due to the small scale of the changes involved and the near total lack of empirical data to rely on. The paleogeographic maps are intended to give a general sense of the spatial and temporal variability inherent in deglaciation environments. Ice boundaries depicted on Figures 6.7 to 6.12 are intended to represent the "Youth" stage of the glacial karst cycle as defined by Clayton (1964); that is, such ice is beginning to stagnate but retains enough horizontal pressure to dam lakes. It also would be characterized by a surface of exposed ice with little accumulation of ablation till, primarily surface drainage, and no lake formation. As the ice down wastes and the glacial karst cycle continues, much of the stagnant ice progresses to the "Mature" and "Old Age" stages of the cycle. These stages were minimal in areal extent prior to 14,000 years ago but became extensive after that.

It is not possible to delineate precise boundaries between mature and old age glacial karst topography and therefore they are depicted as one unit. However, this unit should be envisioned as a heterogeneous mosaic where the stage of the development of the ice in any region is dependent on several factors. One of these is of course the presence or absence of subsequent lacustrine or fluvial sediment being added to the autochthonous debris within the ice mass. As mentioned earlier, the rate of melting is affected by the thickness and texture of this debris layer. Also, as the debris layer becomes thicker and more stable and vegetation is established, the character of the vegetation also may play a part in the varying insulation of the underlying ice.

Legend for Figures 6.7 to 6.12


Lake
Stage I (youth) stagnant ice
Stage II (mature) stagnant ice
Stage II/Stage III (old age) stagnant ice mosaic
Herbaceous vegetation
Shrub vegetation
Arboreal Birch
Spruce
Pine

Sources of data, *ice positions:* Carrara et al. 1986, Dyke and Prest 1987, Bobrowsky et al. 1990;*stage II and II stagnant ice locations:* based on Dyke and Prest 1987 retreat lines and argument in this paper; *lakes:* St. Onge 1972, Matthews 1980, Quigley 1980, Dyke and Prest 1987, Teller 1987; *vegetation:* Lichti-Federovich 1970, Schweger et al. 1981, MacDonald 1982, 1987a, 1987b, 1989,MacDonald and Cwynar 1985, Mott and Jackson 1982, Kvill 1985,Beaudoin 1986, Vance 1986b, White and Matthewes 1986, Reasoner and Hickman 1988, Hickman and Schweger 1991, this work.

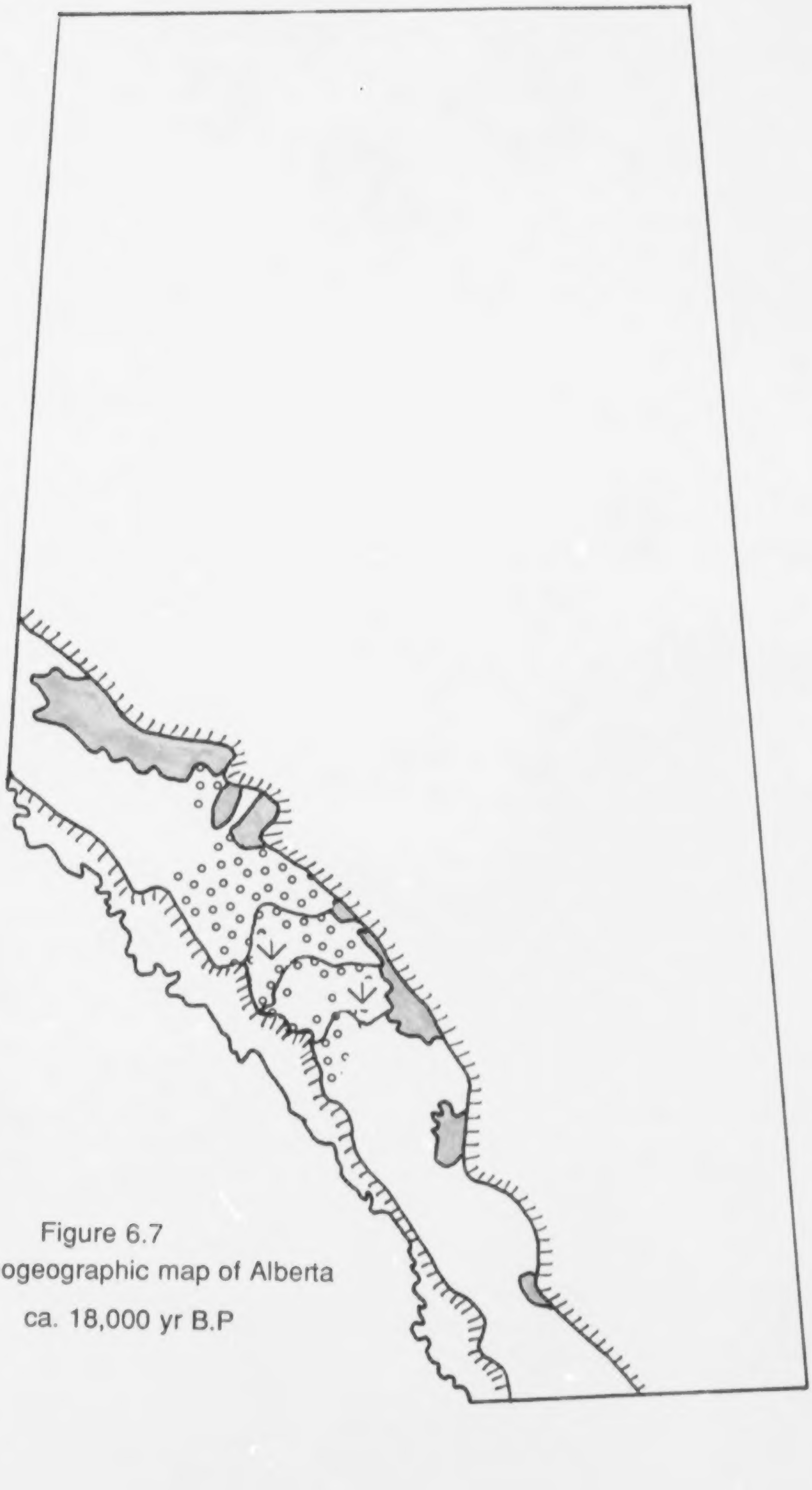


Figure 6.7
Paleogeographic map of Alberta
ca. 18,000 yr B.P

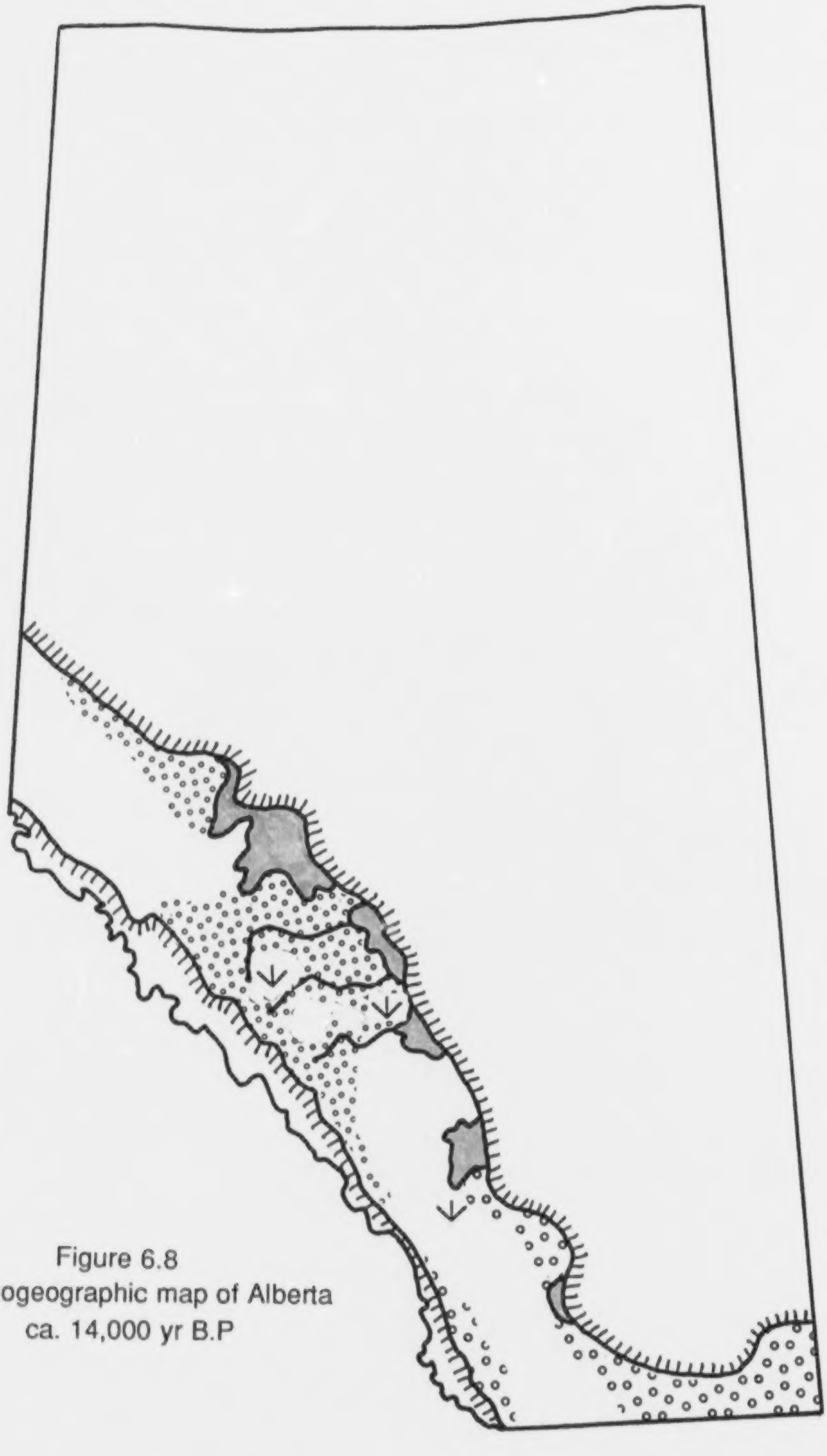


Figure 6.8
Paleogeographic map of Alberta
ca. 14,000 yr B.P

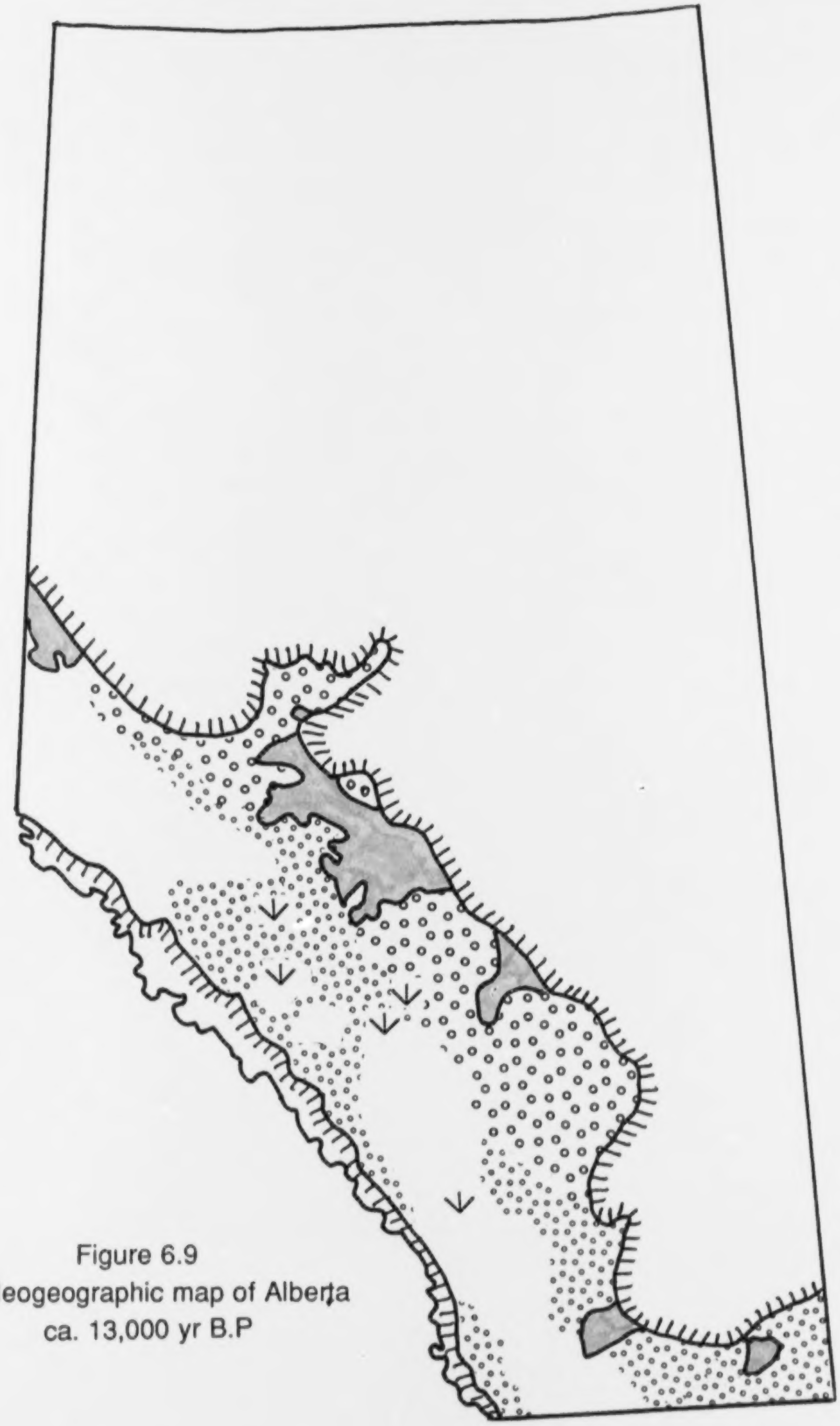


Figure 6.9
Paleogeographic map of Alberta
ca. 13,000 yr B.P

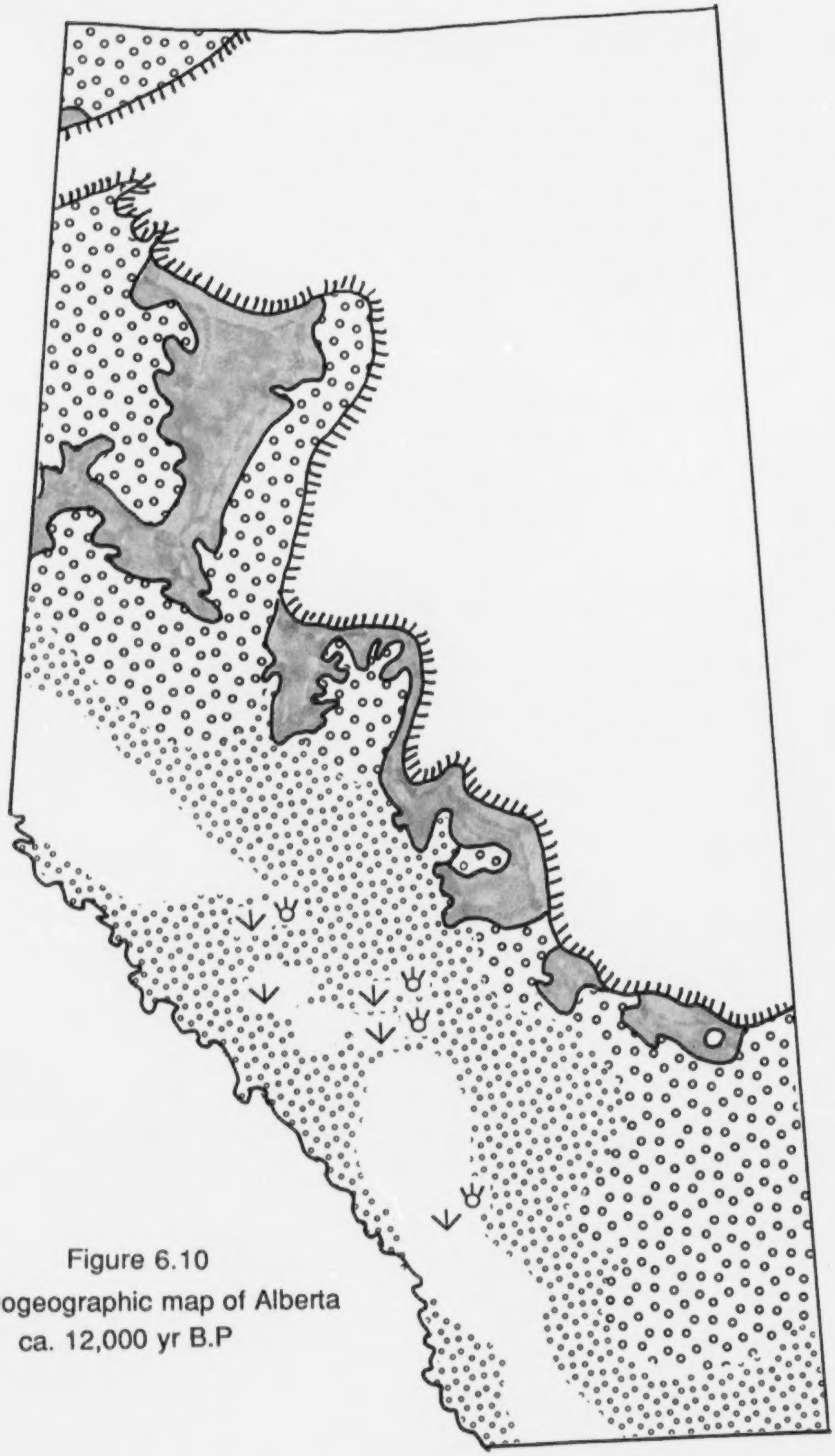


Figure 6.10
Paleogeographic map of Alberta
ca. 12,000 yr B.P

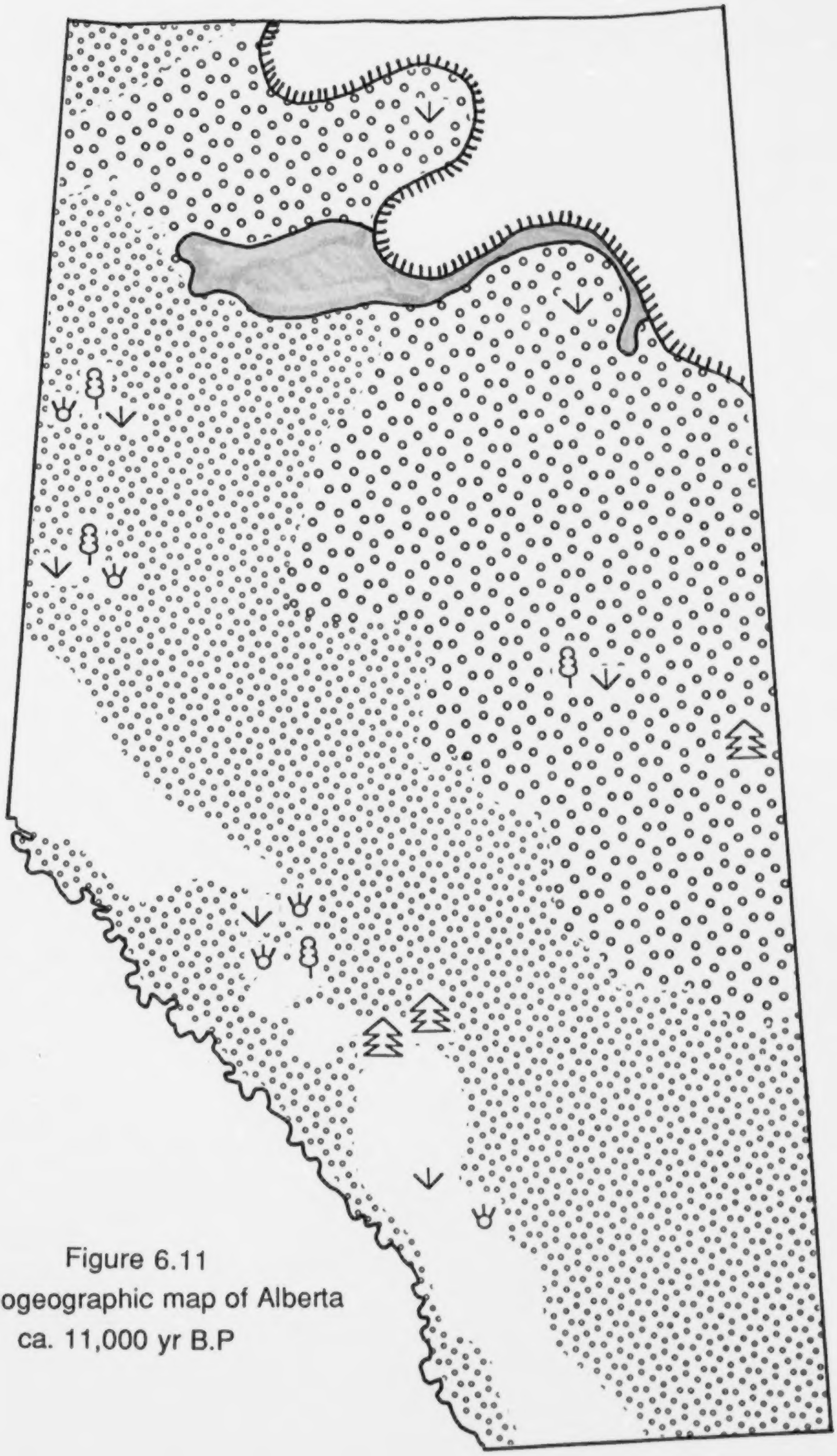


Figure 6.11
Paleogeographic map of Alberta
ca. 11,000 yr B.P

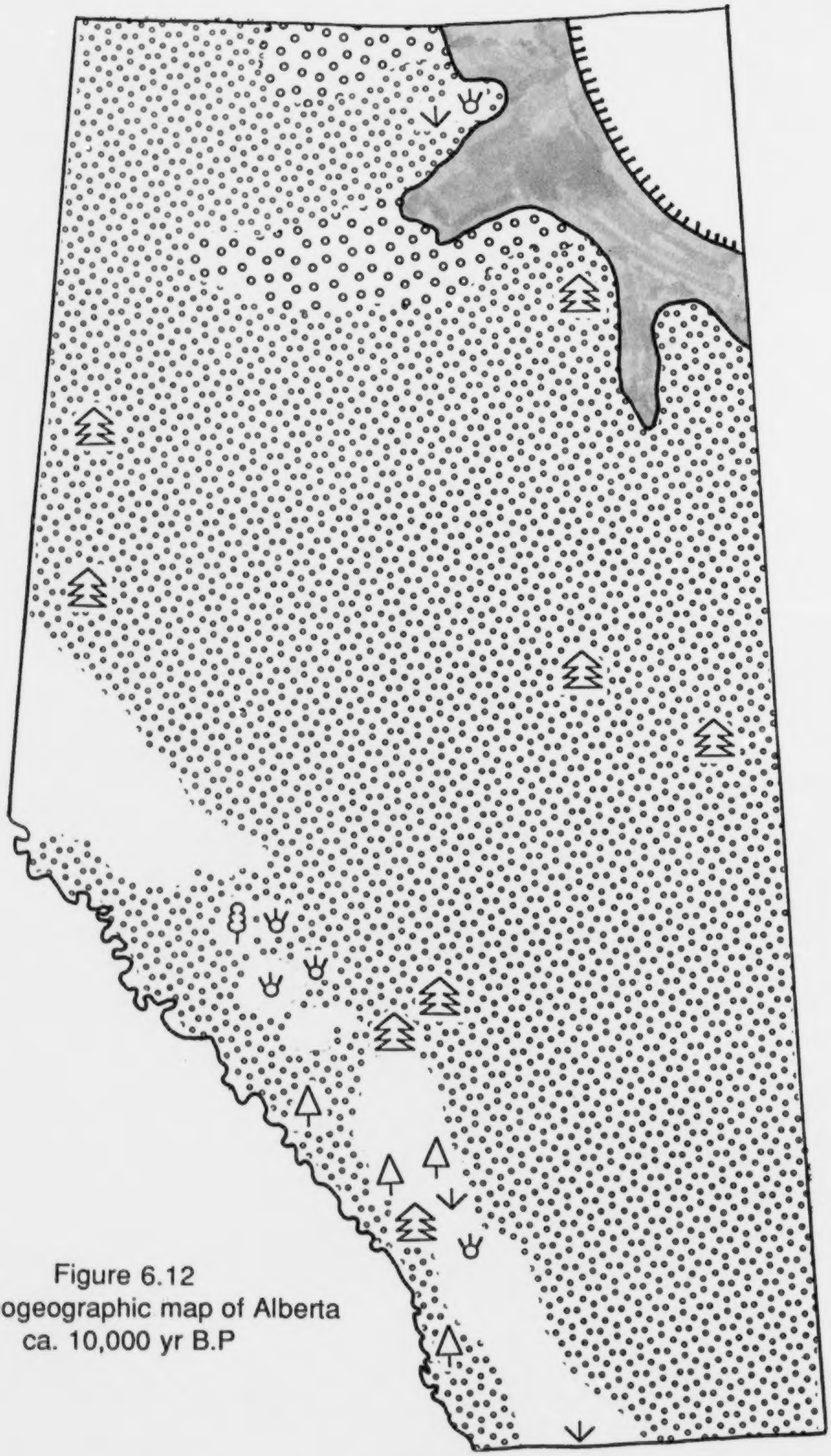


Figure 6.12
Paleogeographic map of Alberta
ca. 10,000 yr B.P

The result is a continually changing surface upon which sands and other well-drained substrates thaw deeper than loams and clays, and south-facing grass-covered slopes thaw more deeply, and are commonly steeper than the slower thawing shrub- and tree-covered north-facing slopes (Nikiforoff 1928: Czudek and Demek 1970). Other important factors contributing to the spatial variability in glacial karst development include initial ice thickness and distance from ice lobe centers; that is, we would expect more mature ice in the vicinity of the young ice in the northeastern portion of Alberta and relatively more old-age ice in a northwest to southeast-trending band across the province. The various stages of the glacial karst cycle are thus present contemporaneously in different areas, providing the basis for the late-glacial ecosystem.

Besides the distribution of ice, in whatever form, the distribution of water is another important aspect of the ecosystem. The large proglacial lakes that formed as the dynamically active/stagnant ice transition migrated to the northeast are indicated on the paleogeographic maps. Not indicated, however, but equally important are the many lakes and "lakelets" (Russel 1893) that would have been ubiquitous throughout areas of mature and old age glacial karst topography. The age or stability of the lakes would not necessarily be equivalent to the age of the accumulated debris layer as Whiteside et al. (1980) point out that young lakes form even on older moraines of the Klutan glacier because of localized melting. Thus there could be a variety of stages of lakes, in various stages of development (steep slopes to gentle, ice slopes to debris covered) in any particular area.

In addition, the behavior of these lakes would be unique due to their glacial karst genesis; that is, it would be common for lakes of assorted sizes from 10 meters to 2 kilometers in diameter, to change level or drain suddenly and subsequently refill, several times a year (Reid 1970; Embleton and King 1975). It is likely that most of these lakes were biologically sterile, mainly due to their instability. Whiteside et al. (1980) feel that warm shallow ponds would have provided a better habitat for zooplankton than deeper, presumably ice-bounded lakes. Whiteside et al. (1980) further note that some lakes on the older moraines of the Martin River Glacier are well insulated, warm, and clear and support normal freshwater plants and animals. Although there is evidence that an abundant faunal assemblage of freshwater mollusca and algae had colonized the stagnant Late Wisconsinan Laurentide ice sheet by the beginning of postglacial time (Emerson 1977:89), evidence that late-glacial lakes in Alberta supported freshwater plants and animals is lacking. Bradbury and Whiteside (1980) noted, however, the possibility that nutrients may have existed up to 300 years earlier than can be detected in the sediments.

Although not an abiotic component of the physical environment, one of the most interesting aspects of this variable, constantly changing landscape is the vegetation it supports. Discussions of late-glacial and early post-glacial vegetation assemblages often address the issue of nonanalogous vegetations, caused by the juxtaposition of species that today normally occupy different ecological habitats. Glacial karst topography offers a particularly suitable edaphic base for mosaics of different types of vegetation. This pattern is evident in the vegetation on the moraines of the stagnant Klutan Glacier, where Birks (1980:75) notes that the mixture of species characteristic of open areas, with forest species and species associated with damp soils, "reflects the environmental heterogeneity of the habitat, with instability, periodic waterlogging, and flooding." The sequence of the Klutan moraines further provides an analogy for the progressive development of glacial karst and the related changes in vegetation. The moraines demonstrate a succession from bare ground to herbaceous to shrub to coniferous vegetation with the progressive build up of humus, organic matter, and nutrients in the surface debris; and illustrate how all this variability may occur in a relatively small area.

Climate has already been discussed. However, to summarize, during deglaciation the climate changed from cold and dry at 18,000 yr B.P., to warm and dry at 14,000 yr B.P., and became more so with a peak circa 10,000 to 9,000 yr B.P. (Delorme et al. 1977; Ruddiman and McIntyre 1981; Schweger and Hickman 1989). The residual mass of Laurentide ice centered over Hudson Bay was apparently still effectively splitting the jet stream and deflecting storm tracks and moisture to the south (Kutzbach and Wright 1986; Barnosky et al. 1987). It has been suggested that it would have been cloudy with storms on the edges of the residual ice mass in the winter with clear skies and brisk outflowing winds in the spring (Manley 1955). Longley (1972) suggests that in areas of extensive lakes (e.g., proglacial lakes bordering the dynamically active ice front)cloud cover may have been extensive in autumn due to evaporation. The prevailing winds, as reflected by fossil dune areas, apparently shifted from primarily easterly to a more southerly direction as the Laurentide ice mass melted back (Odynsky 1959; St. Onge 1972).

6.2.f Paraglacial Processes

The bulk of the above discussion concerned the overwhelming influence of stagnant ice on deglaciation environments in Alberta. Although stagnation was of primary importance in most of Alberta, there are other processes that were locally dominant. In particular, paraglacial processes were of great importance in montane areas, with effects of these processes seen downstream of any major rivers that originate within formerly glaciated mountains and extend onto the Plains (Jackson et al. 1982).

Paraglacial processes are sometimes equated with periglacial processes but this is an inaccurate correlation. Whereas "*periglacial* processes are those for which the *cold temperature*s associated with ice are the operant factor" (Jackson et al. 1982:2229), paraglacial processes occur during deglaciation, when retreat of ice is the operant factor. Jackson et al. (1982:2229) state that of primary importance is "the loss by various ice-marginal deposits of the physical support afforded by the ice lobes. On high slopes the result would be widespread instability and mass wasting regardless of the prevailing temperature."

Paraglacial processes seem to be associated with montane areas and the retreat of active ice. A relatively rapid retreat allows the accumulation of large amounts of unstabilized debris which is available in largely unstable positions for subsequent sedimentation. Paraglacial processes would have "promoted the rapid development of large debris fans shortly after deglaciation of major mountain valleys" (Jackson et al. 1982:2229). They also would have added large amounts of coarse sediment to the drainage system (perhaps to be eventually deposited in proglacial lakes over stagnant ice to the east).

Although paraglacial processes were operant in an areally limited portion of Alberta, they have larger potential consequences for the elucidation of early human occupation of the province. It is precisely the areas most likely to have been suitable locations for early human habitation (the major drainage systems of the Front Ranges) that were particularly subject to the instability and subsequent aggradation of immense volumes of sediment. Jackson et al. (1982) estimate that 80% of the debris flow activity took place in the early millennia after deglaciation, which are the millennia of most importance to archaeologists looking for early sites. It is not unlikely that the majority of any once extant late glacial archaeological sites are presently buried below extensive montane debris flows.

7. Regional Analysis

7.1 The Regional Approach

The ecological approach focusing on the dynamic interrelationships between humans and their environment must have a regional focus (Section 1.2.b). The region of interest here is the upper North Saskatchewan drainage basin (Fig 7.1). It is "the archaeologist's task to delineate the region under study" (Bar-Yosef 1987:220) and to justify the validity of their choices. It is not mandatory that physiographic features selected to define a region reflect actual cultural boundaries; they may instead "mainly provide a means for subdividing a large geographic area" (Greiger 1985:1). "When we choose a particular scale during one moment of our analysis, we do so because at that effective scale we can comprehend patterns" (Crumley and Marquardt 1990:74).

Although the goal of this study is to evaluate human viability in the "ice-free corridor," the data presented here only pertain to a portion of the corridor. Criteria are required for subdividing the corridor into a reasonably sized region for analysis. It has been observed "that the boundaries of regional populations of hunters and gatherers frequently coincide with the area marked by a drainage basin" (Gamble 1984:241). Rogers (1969) noted, for example, that local group territories of the Cree and Ojibwa of northeastern Canada correspond well to drainage basins. Drainage basin boundaries also apply to regional groups in northwest Alaska (Burch and Correll 1972), Australia (Peterson 1976), and aboriginal New England (Snow 1981). In Alberta, McCullough and Fedirchuk (1986), relying on the demonstrated association between cultural groups and areas circumscribed by drainage basins, have suggested dividing the Eastern Slopes (foothills) of Alberta into areas based on upper river drainage

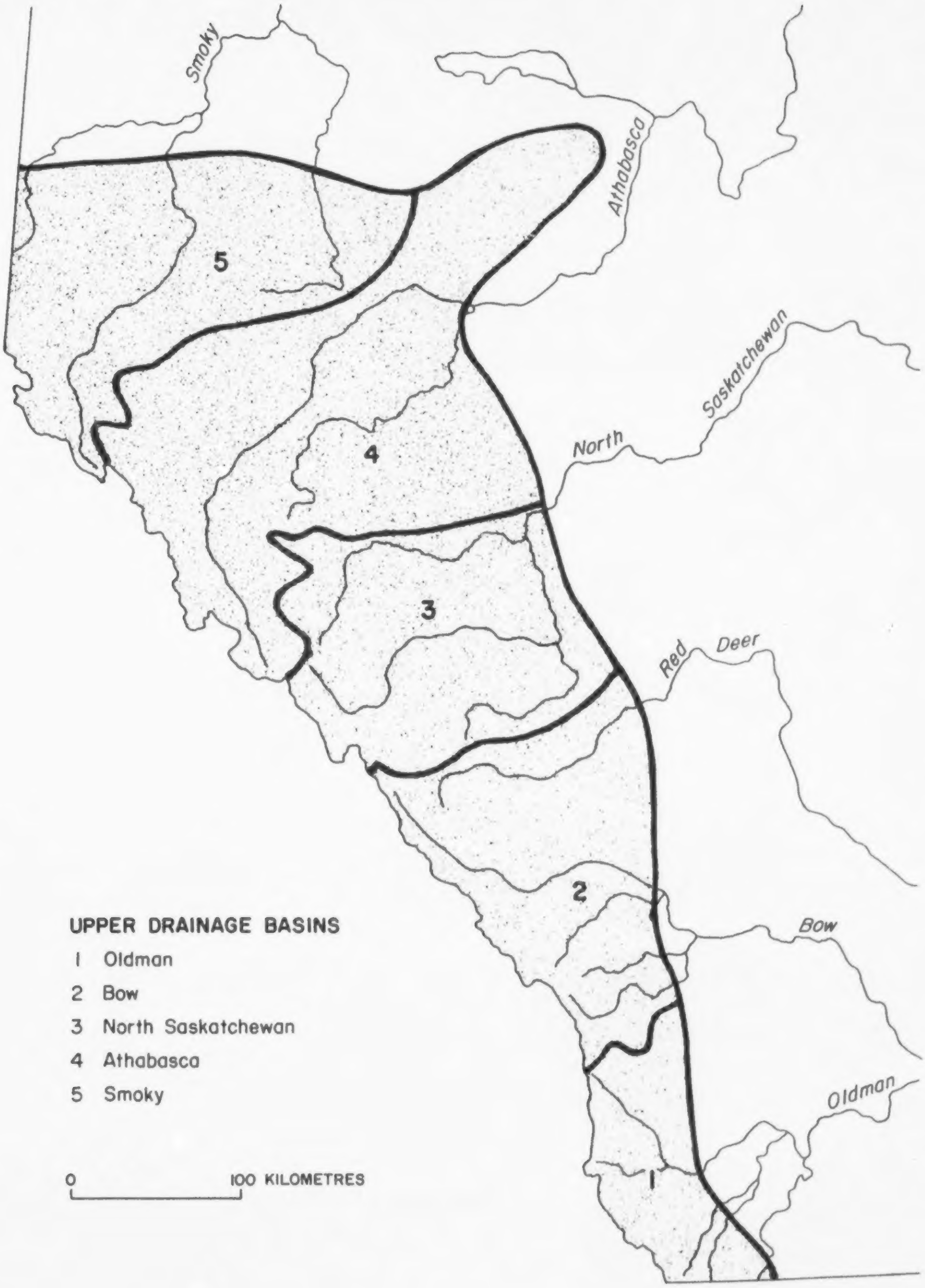

Smoky
Athabasca
North Saskatchewan
Red Deer
Bow
Oldman
5
4
3
2
1
UPPER DRAINAGE BASINS
1 Oldman
2 Bow
3 North Saskatchewan
4 Athabasca
5 Smoky
0
100 KILOMETRES

Figure 7.1 Upper North Saskatchewan Drainage Basin Location Map. From McCullough and Fedirchuk (1986:Figure 2). Reproduced with permission of the Archaeological Survey, Provincial Museum of Alberta.

systems. These areas, "termed regions, constitute ideal collection units for studying past human responses to varying local environments" (McCullough and Fedirchuk 1986:22). Thus there is ample justification for delineating the upper North Saskatchewan basin, for which a paleoenvironmental vegetational reconstruction has been developed, as the unit of analysis.

But how exactly does one evaluate human viability of an environment? There are two broadly different possible methodological approaches to evaluating the environment, 1) general qualitative comparison, and 2) specific quantitative testing. There are drawbacks to either method. The first approach, though comprehensive, is not precise or specific. The problem with the second approach is that although it may appear "impressive" due to numbers, diagrams, and complicated calculations, when the assumptions and imprecise data the calculations are based on are considered, it may actually be less informative than the first approach.

All modelling efforts are "constrained by the complexity of the real world" (Moore 1981:196). According to Levins (1966), models can be either 1) realistic and precise; 2) general and precise, or 3) realistic and general. Models of type one "lend themselves most readily to a rigorous hypothesis-testing approach" (Moore 1981:96). Models of type two have a different methodological orientation; there is no longer an expectation of

> an exact tie between the implications of the general model and the conditions of reality . . . the model stands as an ideal construct, a research instrument against which the complexity of the world is gauged. The patterning of the deviations from the model becomes the focus of research; hypothesis testing is no longer the major concern of this approach to research (Moore 1981:197).

With models of type three, "qualitative rather than quantitative results are sought . . . model predictions are expressed as trends between polar states of the controlled variable" (Moore 1981:1197).

Returning again to the two approaches employed here to evaluate the environment, we can see that general qualitative comparison qualifies as a type three model; i.e., realistic and general. Specific quantitative testing of the environment, though usually assumed to be type one is, due to the constraints of ecosystem complexity, in actuality type two; i.e., general and precise. Thus we can say that the general qualitative comparative method lacks in precision owing to the necessity for simplication and a "lack of quantitative operational measures for critical variables" (Dyson-Hudson and Smith 1978:37). And the specific quantitative method, while precise, is not realistic owing to the impossibility of replicating the dynamic variables of the real world on the scale required.

7.2 A Qualitative Approach

7.2.a Cross-Cultural Comparison

There is a common assumption of association between various "limiting factors", e.g., low temperature, rainfall, primary productivity, and the human carrying capacity of an environment. Generally that is all it is — an association — unspecified, unquantified, never really explained beyond the intuitive sense that extreme environmental conditions limit human cultural systems. What is needed is an understanding of the mechanisms that relate, for example, primary production to humans and their behavior. This understanding can be attained through what Binford (1991:284) calls theory building; i.e., "the intellectual ability to explain the observed variability in terms of general conditions".

In order to gain this understanding and thus a better approach to method two (specific quantitative testing), method one will be utilized to do a general qualitative comparison of high latitude full- and late-glacial environments and human social systems. Of course, the phrase "general qualitative comparison" is just another way of referring to one of the unifying principles of anthropology, the comparative method. Obviously one cannot expect to understand paleolithic adaptations by focusing on one example, one point in time, one spot on earth. Archaeologists must realize that what they "happen to be observing in its particularity might be more profitably seen against a backdrop composed of a much larger scale of observations and arguments regarding causality and variability" (Binford 1991:276).

For example, the richness of the record from the Perigord region of France and the "mammoth hunters" of the Central Russian plain have led to a fallacy of "hasty generalization" and the myth of lush ice age environments, when in fact southwest France and central Russia may be the "exceptions to the rule" of mid to high-latitude hunter-gather paleolithic adaptations. Clearly we need to understand the range and effects of variables in the physical, biological, and social environments if we are ever to discern general principles affecting human behavior (Milton 1984:21). "The peopling of the Americas was merely one part of a larger, global migration, which involves general demographic, social, and cultural processes in a variety of ecological settings" (Dillehay and Meltzer 1991:293). Thus, ultimately, the focus is on context, particularly on putting northwestern North America and the ice-free corridor into global context.

Any area of the earth can be called

> a 'region' for purposes of the study of human-environmental relations, so long as one can recognize within it demonstrable

> homogeneity. But such a region is inadequately conceptualized in the sense that both its temporal relations (connections with the past and the future) and spatial relations (connections with other areas at the same scale and of larger and smaller scales) are unspecified. This difference, prevalent in spatial approaches . . . can be rectified . . . by utilizing a multiscalar (hence, multiregional) and multitemporal analytical strategy (Crumley and Marquardt 1990:75).

Then we can see how it relates as part of the ebb and flow pattern of human cultural occupation and settlement. This is a better approach than a purely particularistic view focusing on the corridor in isolation.

7.2.b The World at 18,000 B.P.

One way to investigate spatial and temporal variability at the multiregional level is to compare settlement histories of different regions (Gamble 1984:248), with the goal of discerning "behavioral regularities which can be explained in terms of cultural or ecological processes" (Greiser 1985:4). Concentrating on the late glacial maximum, a time of global temperature minima, provides the "opportunity to test the effect of environmental selection on patterning in the archaeological record" (Gamble and Soffer 1990b:6), and the impact of environmental change on the expansion and contraction of human populations (Gamble and Soffer 1990b:14).

Gamble (1984, 1986) does this analysis for Europe, using latitude, longitude and relief as benchmarks against which to observe variation. In addition to the above factors, which relate to variations in solar radiation, growing season, and primary productivity, major drainage basins provide justification for division of Europe into regional units of analysis. Following Gamble, this comparative analysis utilizes comparable analytical regions and expands them out from Europe (Fig. 7.2).

The size and boundaries of the regions for which information is

Legend for Figure 7.2

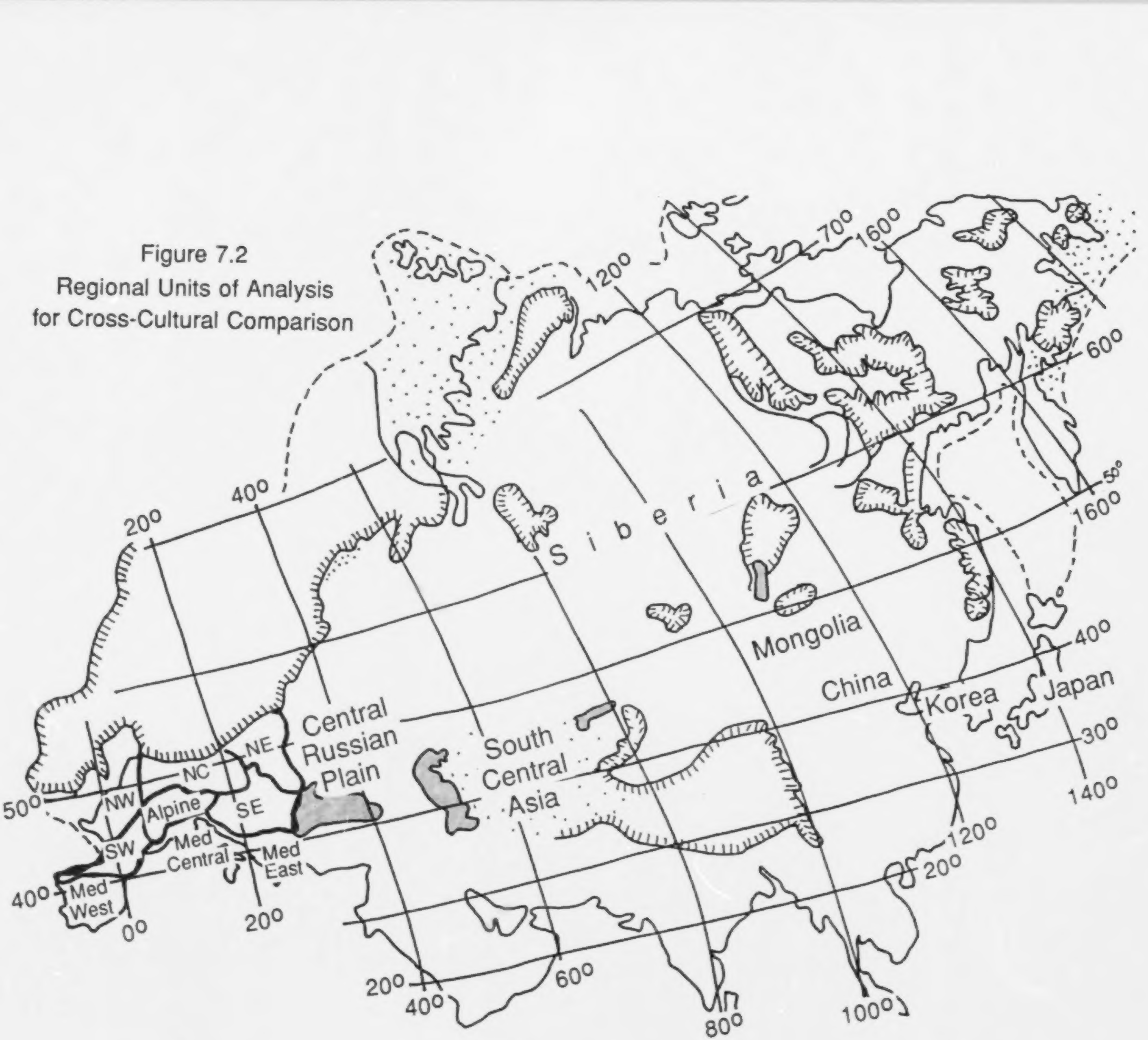
▥ Ice, whether continental or mountain

░ Desert, whether arid or arctic

⬬ Lakes

— — — — Coastline at glacial maximum

Figure 7.2
Regional Units of Analysis
for Cross-Cultural Comparison


Siberia
Mongolia
China
Korea
Japan
Central Russian Plain
South Central Asia
NE
NC
NW
Alpine
SE
SW
Med Central
Med East
Med West
0°
20°
40°
60°
80°
100°
120°
140°
160°
70°
60°
50°
40°
30°
20°

available varies greatly, as does the thoroughness of research from area to area. "Research in some areas, admittedly small in size in global perspective, has been extensive enough to move beyond issues of chronology and culture history and to consider questions of past settlement systems, [whereas] in other cases the sparseness of past research does not permit statements beyond simple documentation of sites occupied around the LGM [Late Glacial maximum]" (Gamble and Soffer 1990b:15). In addition to the imbalance of research between regions is the problem of variations in literature accessibility (Madeyska 1990:24). Furthermore, although the implication is that only evidence ca. 18,000 years B.P. is to be considered, following the books from which this section's title was borrowed, it is not possible to limit the scope strictly to 18,000 B.P. precisely. Most contributors to The World at 18,000 B.P., Vols 1 and 2, considered the period between 22,000 and 14,000 B.P., which allows "the opportunity to examine longer term responses to the climatic minimum (Gamble and Soffer 1990b:9). Trends become clearer when one observes settlement patterning and distributions before, during, and after the last glacial maximum.

7.2.b.1 Northwestern Europe

Northwestern Europe, a region including the northern half of France, Belgium, the Netherlands, and the unglaciated southern area of Britain, is described as having been a polar desert during the last glacial maximum (Gamble 1986: Fig. 3.1,92). These high latitude lands, close to glacial ice, were characterized by very low temperatures, extreme aridity, high winds, and permafrost; and a resulting decrease in vegetation and faunal abundance and diversity (Jochim 1987:321; Schmider 1990:43). Although there is evidence of abundant human occupation prior to 25,000 years ago, after about 22,000 to 19,000 years ago the area was essentially devoid of human settlement until ca. 16,000 to 15,000 years ago (Montet-White 1984:14, Schmider 1990:51; Otte 1990:54, Gamble 1986:205; Price 1991:201). It appears that as glaciers advanced to maximum positions, environments deteriorated and the extreme conditions in this region "became so inhospitable to human occupation that groups there became extinct" (Soffer 1987b:335).

7.2.b.2 North Central Europe

Conditions in North Central Europe were similar. This region, including Germany, most of Czechoslovakia, and western and southern Poland (Gamble 1986:Fig. 3.1), was in a glacial corridor caused by the expanding Scandinavian and Alpine glaciers (Gamble 1984:253, Weniger 1990:173). During the maximum extent of ice between ca. 20,000 and 18,000 years ago the northern and southern ice borders were only 600 km from each other (Weniger 1990:173). Numerous periglacial features, such as frost cracks, solifluction and cryoturbation, along with very sparse arid-adapted vegetation, indicate a harsh, cold, dry environment that has been described as arctic desert (Jochim 1987:321, Weniger 1990:173) or very cool steppe (Kozlowski 1990:210). As was the case in northwestern Europe, this region also shows abundant evidence of human occupation in the millennia prior to the glacial maximum. Numerous sites, e.g., Dolni Vestonice, date prior to 24,000 years ago (Gamble 1986:183; Weniger 1990:173; Kozlowski 1990:211). Between 24,000 and 18,000 years ago there was a continued decrease in site numbers, and after 18,000 years ago there is only one site in Germany that may date to between 18,000 and 15,000 years ago. Although Jochim (1987:322) states there are no sites in Moravia that date to the last glacial maximum, Svoboda (1990:198) cites one site (Stronska Skala IV) with dates of ca. 18220 +/- 120 and 17740 +/- 90 yr B.P., which he describes as a task- specific horse hunting station characterized by high percentages of exotic lithics. Thus the only firmly dated site in the entire region is found south of the 50^{o} N latitude and may represent a distant hunting station utilized in the peripheral zone of a wide-ranging logistically-oriented group of hunter-gathers located far to the southwest. This is ample evidence to argue for a severe decrease in population density or complete depopulation during the last glacial maximum.

7.2.b.3 North Eastern Europe

The North East region of Europe is defined here as consisting of northeastern Poland, Latvia, Lithuania, most of Belarus, and the northwestern corner of Ukraine. Although Gamble (1986: Fig 3.1) includes the entire western two-thirds of Ukraine in his "North East" region, that area will be discussed as part of the Central Russian plain. The North East region is described by Kozlowski (1990:210) as very cool steppe with an increase in dwarf birch ca. 20,000 to 17,000 years ago, and as tundra-steppe by Velichko and Korenkova (1990:Plate I). As with the North Central region, the North East region has evidence of occupation prior to 24,000 years ago; however, in this case there is no evidence of settlement during the glacial maximum (Kozlowski 1990:211).

7.2.b.4 South Western Europe

Southwestern Europe consists primarily of the southern half of France and the north coast of Spain (Gamble 1986: Fig 3.1). Although the classic Upper Paleolithic occupations of southwest France are traditionally envisioned within a tundra or arctic-like environment, recent evidence suggests otherwise. White (1985:43) describes the vegetation as a varying mix of steppe and forest species, and Otte (1990:Fig. 3.1) maps the region as consisting of forest-tundra, and open pine, oak and elm forest with some alpine areas. This forest-tundra vegetation mosaic was the home of a diverse faunal assemblage, that along with the abundant caves, rock shelters, and lithic sources in the area, provided an ample resource base for human occupation (White 1985:51). Although the region experienced a decrease in climate and faunal diversity during the late glacial maximum, unlike the northern regions discussed above, there is evidence for continuous human settlement, though at lower population densities than before or after (Rigaud and Simek 1990:83; Hayden et al. 1987:280). The region is seen as a major source area for the recolonization of northern and eastern areas when environmental conditions ameliorated in the late-glacial (Gamble 1986:213).

7.2.b.5 Alpine Europe

Alpine Europe is the area containing Switzerland, Austria, and the extreme northern part of Italy (Gamble 1986: Fig 3.1). Much of this region was covered by ice during the last glacial maximum, and the open land around the glaciers was covered in alpine vegetation (Otte 1990:Fig 3.1). Although there is evidence of earlier occupation in this mountainous area, there is no evidence from ca. 32,000 years ago until essentially postglacial times, with late Magdalenian sites in both the southern and northern alpine regions dating to 13,000 and 12,000 yr B.P., respectively (Gamble 1986: 197,219). Thus the evidence indicates the area was unoccupied during the last glacial maximum and for several millennia on either side.

7.2.b.6 South Eastern Europe

The South Eastern region of Europe is defined as including Hungary, Romania, northeastern Yugoslavia, and northern Bulgaria (Gamble 1986: Fig. 3.1). This region is described as very dry during the last glacial maximum; an estimated 50% reduction in precipitation, with loess deposition indicate an arid continental climate (Gamble 1986:102). The vegetation is described as steppe and forest-steppe (Gamble 1986: Fig. 3.4), with "woodland restricted to sheltered gallery locations along major river courses [consisting] of dwarf shrubs and willow" (Gamble 1986:102).

The area contains Aurignacian assemblages dating to ca. 43,000 to 29,000 yrs ago (Gamble 1986:194), and Gamble (1986:218) states that there is no subsequent hiatus in sites around the last glacial maximum, citing sites in Hungary dating to 19,500 to 17,000 years ago (Gamble 86:219). Kozlowski (1990:219), however, notes that there are few sites dating to between 22,000 and 15,000 years ago. Thus while there may have been a decrease in population density, there doesn't appear to have been a complete depopulation of the area during the last glacial maximum.

7.2.b.7 Western Mediterranean

The Western Mediterranean region consists of Portugal, most of Spain excluding the north coastal area, and the southern Mediterranean coastal area of France (Gamble 1986:Fig 3.1). The vegetation at glacial maximum is described as arid steppe (Gamble 1986:102), which may have supported a fairly rich fauna including horses, ibex, and aurochs (Strauss 1990:93; Gamble 1986:110). There is evidence of Aurignacian settlement from ca. 30,000 to 20,000 years ago, and Solutrean from 20,000 to 18,000 years ago until replacement by Magdelenian sites ca. 13,000 years ago (Gamble 1986:199,236). Thus it appears the western Mediterranean region was occupied continuously throughout the last glacial event, including the glacial maximum (Gamble 1984:253).

7.2.b.8 Central Mediterranean

The Central Mediterranean region essentially consists of Italy (Gamble 1986:Fig 3.1). The vegetation in Italy during the last glacial is described as arid steppe (Gamble 1986:102). Human occupation in the region appears to have been abundant in the early stage of the last glacial ca. 75,000 to 32,000 years ago (Gamble 1986:174), nonexistent during the middle interstadial period ca. 30,000 to 25,000 years ago (Mussi 1990:139), and abundant once again during Epigravettian times from ca. 19,000 to 12,000 years ago (Gamble 1986:237). Thus the area was clearly occupied during the last glacial maximum.

7.2.b.9 Eastern Mediterranean

The Eastern Mediterranean region is coincident with the Balkans; that is, Albania, Greece, and the southern parts of Yugoslavia and Bulgaria (Gamble 1986:Fig 3.1, Bailey and Gamble 1990:148). The area contains mountainous and rugged topography and experienced local glaciation during the last glacial (Bailey and Gamble 1990:150). The vegetation is described as having been made up of forest steppe and arid steppe (Gamble 1986: Fig. 3.14; Bailey and Gamble 1990:148), associated with an estimated 50% reduction in precipitation (Gamble 1986:102).

The region exhibits occupation during the early stage of the last glacial ca. 75,000 to 32,000 years ago (Gamble 1986:174), and up until 26,000 years ago (Gamble 1986:200). Occupation may extend throughout the last glacial and up until the late Epigravettian ca. 10,000 ya in Yugoslavia and Greece, although evidence is sparse between 20,000 and 16,000 years ago (Gamble 1986:237; Bailey and Gamble 1990:151). The higher elevations in particular appear to have been completely abandoned during the last glacial maximum (Bailey and Gamble 1990:165). Thus, while population appears to have been sparse during the glacial maximum, there is no clear evidence for complete depopulation.

7.2.b.10 Central Russian Plain

The Central Russian Plain is the area north of the Black Sea including eastern Romania, Moldova, Ukraine, Belarus and western European Russia. During the last glacial maximum, however, when ice sheets extended south to 52^0 N latitude in parts of the study region, much of the latter two areas would have been covered by ice. During the last glacial maximum the region was extremely dry and cold, with periglacial steppe and forest-steppe vegetation; forest growth being restricted to river valleys (Soffer 1985:174). Important settlement loci in the region are three major river systems, the Dnester, Dneper and Don, all of which are aligned roughly in a north-south direction.

Kozlowski (1990:223) reports that although there was a hiatus at Molochov V between 23,000 and 16,760 years ago in the northern part of the Dnester basin in Moldova, there was apparently continuity in the south. He does not see a total decline in settlement, but movement to the south and east (Kozlowski 1990:225). For the central and eastern parts of the plain, associated with the Dneper and Don rivers, Soffer (1985:173) had originally argued for an occupational hiatus from 20,000 - 18,000 during the Valdai maximum. This conclusion was in contrast to abundant evidence of occupation prior to (ca. 26,000 to 20,000 years) and after (ca. 18,000 to 12,000) the glacial maximum (Soffer 1985:173).

Soffer (1990:228) now notes that there are new sites dated to the 20,000 to 18,000 year interval. These dates, however, are on mammoth bone. Thus the dating problems include both the inherent difficulties with bone dating and the very great possibility that bones utilized by humans had been collected from animals long dead. It seems likely that scavenging for mammoth bone played a significant role in allowing human settlement in the region, as it was used not only in the construction of dwellings, but as a primary source of fuel (Soffer 1985:258; 1990:236). Overall, the archaeological evidence indicates decrease to low population densities or abandonment in northern regions, combined with movement to the south and southeast (Soffer 1985;1990). Thus even this relatively densely settled region, which later served as a source of recolonization of surrounding areas (Gamble 1986), suffered significant population decline during the glacial maximum.

7.2.b.11 South Central Asia

South Central Asia is a very large region of approximately 2,400,000 km^2 (Davis 1990:266), made up of the republics of Kazakhstan, Turkmenistan, Uzbekistan, Kyrgyzstan, and Tajikistan. It lies between the Caspian Sea on the west, China on the east, and Iran and Afghanistan on the south. The northern border, "marked by the transition of the vast Karath steppes to the western Siberian lowlands " (Davis 1990:266), varies between 50^{o} and 55^{o} N latitude.

The region is now classed as a desert and steppe region of pervasive aridity (Davis 1990:266). During the last glacial maximum, conditions were significantly cooler and drier, causing a change from a warm and semiarid steppe to cool and arid semi-desert (Davis 1990:269). A decrease in grasses and increase in deep-rooted shrubs resulted in "vast areas of dry *Artemisia* steppe [characterizing] much of the Central Asian landscape" (Davis 1990:272). Although there is evidence of human occupation in the area back to 800,000 years, "the Upper Paleolithic is a big mystery, especially around the LGM [late glacial maximum] at 18,000 B.P. After some 40 years of research there are only a handful of Upper Paleolithic sites, and not one of them can be dated with confidence to the LGM" (Davis

1990:266). In particular, the plains between the Caspian and Aral Seas and Lake Balkhash were depopulated during the last glacial maximum and perhaps the entire interval between 22,000 and 14,000 B.P. (Madeyska 1990:29; Davis 1990:273). The three or four known Upper Paleolithic sites within South Central Asia do not date to the glacial maximum and are found outside the plains region in the higher, less arid plateau areas in the extreme southeast of the study region (Madeyska 1990:29; Davis 1990:274).

> On the basis of the current evidence, it appears that Central Asia was very thinly populated, if at all, during the LGM. The relatively abundant pre-and post-Upper Paleolithic sites certainly indicate that hunters and gatherers certainly could adapt to semi arid steppe conditions, but the quite cool and very arid conditions of the LGM simply may not have allowed the flourishing of an adequate or reliable resource base (Davis 1990:272).

Thus, "although it is never comforting to deal with negative evidence . . . the archaeological evidence is consistent with the hypothesis that climatic deterioration led to a depopulation of Central Asia during the [last glacial maximum]" (Davis 1990:273).

7.2.b.12 Siberia

Siberia, the vast area of northeastern Eurasia located entirely within the permafrost zone, suffered from extremely severe climatic conditions during the last glacial maximum (Velichko and Korenkova 1990:255). The period between ca. 22,000 to 19,000 years ago is described as humid, with increasing cold, while the period of ca. 17,000 to 16,000 years ago is characterized by extremely low temperatures and high aridity (Madeyska 1990:32; Velichko and Korenkova 1990:258).

The resulting vegetation ranged from xerophytic periglacial steppe and steppe-tundra in the south to tundra-steppe and tundra in the north to tundra and arctic and polar deserts in the extreme eastern portion that constituted western Beringia, all underlain by extensive development of permafrost (Madeyska 1990:32; Velichko and Korenkova 1990:258; Laughlin and Harper 1988:26). A variety of large-sized herbivores were associated with this nonarboreal vegetation, including reindeer, mammoth and musk ox (particularly in the northern areas), and horse, bison and onager (particularly in the southern areas) (Madeyska 1990:32; Velichko and Korenkova 1990:259). It is felt that in spite of the extremely severe climatic conditions "the high animal biomass these regions supported acted as a magnet for human settlement" (Velichko and Korenkova 1990:258) during parts of the last glacial episode. This characterization, however, appears to apply mainly to the extreme western parts of Siberia as Upper Paleolithic faunal finds are scarce in the east (Laughlin and Harper 1988:26).

There are apparent clusters of Upper Paleolithic settlement in the region, particularly along the Yenisei, Angara, and upper Lena Rivers west of Lake Baikal in the south central area of Siberia, and along the Aldan River in eastern Siberia (Madeyska 1990:Fig 1.1). Madeyska (1990:32) notes that most of the sites are associated with the first phase of the Sartan, i.e., prior to the last glacial maximum, while Velichko and Korenkova (1990:259) state that the absence of sites in central and eastern Siberia during this period "indicates either that this region still remained unoccupied, or, if occupied, then was inhabited at extremely low densities." Although pre-glacial maximum dates from Diukhtai on the Aldan River have been reported (Mochanov 1978), most archaeologists question the early dates and suggest while Diukhtai might possibly date as old as 18,000, the most likely time of occupation was between ca. 14,000 and 12,000 years ago (Praslov 1984; Clark 1988). Thus archaeological evidence suggests that human settlement was sparse to nonexistent during the last glacial maximum.

7.2.b.13 China and Mongolia

China experienced a cold dry climate during the last glacial period accompanied by the deposition of significant amounts of loess (Chen and Olsen 1990:276). Faunal remains from North China dated to the last glacial maximum indicate a mixed desert and grassland environment (Chen and Olsen 1990:277). There are numerous Upper Paleolithic sites in China and at least two securely dated to the last glacial maximum (Chen and Olsen 1990: Fig. 15.1). All these sites, it should be noted, are located south of 40^{0} N latitude. Madeyska (1990:29) reports two sites from Mongolia north of the Chinese border. However, dates of ca. 20,000 and 10,000 years ago are assumed to indicate continuous settlement, which in fact cannot be demonstrated without finer chronological control. Thus, there is not definitive evidence of human presence north of 40^{0} N latitude and east of 110^{0} E longitude during the last glacial maximum on the eastern Eurasian mainland.

7.2.b.14 Japan and Korea

During the last glacial several Japanese islands were connected to each other and to Sakhalin to the north. The temperature is described as extremely cold but variable with vegetation characterized as ranging from arctic in the north, and boreal in the central regions, to temperate in the south (Reynolds and Kamer 1990:296). There is evidence for human occupation throughout the last glacial maximum. The archaeological record is interpreted as reflecting evidence of high residential mobility resulting in short duration/repeated-use sites (Reynolds and Kamer 1990:304). Chard (1974) suggests the archaeological record reflects a population increase during the last glacial maximum. However, Reynolds and Kamer (1990:306) note that "it must . . . be remembered that the Japanese Islands have been very intensively occupied and this may well be a biasing factor in the documentation and interpretation of the Japanese Palaeolithic" (i.e., population increase is not definitely demonstrated for the last glacial maximum).

Although few paleoenvironmental studies have been done for Korea, it is believed that the vegetation during the last glacial would have been made up of mixed coniferous and deciduous forests (Reynolds and Kamer 1990:306), perhaps comparable to the boreal and temperate zones of the time in Japan. The vegetation supported a varied fauna, including wild ox and several types of deer (Reynolds and Kamer 1990:307). There is one site in South Korea that dates to before the last glacial maximum at ca. 21,000 years ago (Reynolds and Kamer 1990:308). The site is located at approximately 35°N latitude. That this is the only site in Korea dating to the last glacial may be a reflection of a paucity of research on the Paleolithic.

7.2.b.15 Australia and Tasmania

The southern latitudes are often ignored in consideration of high latitude conditions. However, Tasmania and the high latitudes of Australia (which were part of a single continent at the time) were affected by glacial conditions in a period when humans were clearly present, offering a valuable analogy of human/glacial interaction for study. At the time of the last glacial maximum "it has been estimated that the edge of the winterpack ice around the Antarctic continent may have extended approximately 1000 km north of its present position, and that the Antarctic polar front may have been situated at 45°, i.e., only a few hundred kilometres to the south of Tasmania" (Jones 1990:266). The intensified pressure systems that resulted would have contributed to generally arid, windy, and dusty conditions during the last glacial maximum in both Tasmania and southern Australia (Jones 1990:268).

In Australia valley glaciers formed in the southeast highlands and were accompanied by periglacial zones, lowered treeline, and a varied vegetation composed of alpine desert, cold steppe, shrub, and grassland and herbfield (Dodson 1989:212; Jones 1990:268). At the maximum of the last glacial period 18,000 years ago, the climate was extremely dry and cold and the arid and semiarid vegetation expanded (Dodson 1989:213). Although it is known that most ecological zones of Australia were colonized by 25,000 years ago, including parts of the arid interior, foothill zones, and central desert (Smith 1987), this early settlement apparently did not extend to the upper elevations (White and O'Connell 1982:54; Jones 1990:265; Beaton 1991:216). Furthermore there are no known last glacial maximum sites within the upper elevations although there are a few sites in the desert interior at this time (Flood 1976:30; Jones 1990:278). The highlands of southeastern Australia, which even today are cold, windy, and treeless, may have been uninhabited until approximately 6000 years ago (Flood 1976:32).

During the last glacial maximum, southern Tasmania experienced glacial conditions with glaciers forming in several valleys (Cosgrove, Allen, and Marshall 1990:60), resulting in approximately 5000 km^2 being covered with ice (White and O'Connell 1982:157). The temperature began to decrease approximately 24,000 years ago with the maximum cold dated to ca. 19,000 to 18,000 years B.P. (Jones 1990:278). The climate is described as "glacial-arid," i.e., cold, dry, and windy with extensive periglacial zones (Cosgrove et al. 1990:62; White and O'Connell 1982:157; Jones 1990:276). Although the vegetation has been described as cold grassy plains (White and O'Connell

1982:157), and tundra or herbfield (Jones 1990:276), Cosgrove et al. (1990:62), denying what they call the "myth" of herbfield and steppe, argue for a vegetation of "stunted woody, sedge and heath taxa similar to modern alpine and treeless subalpine trees" with grassland restricted to limestone valleys and alluvial soils.

There is evidence of human occupation of the Tasmanian uplands prior to 30,000 years ago (Cosgrove et al. 1990:59), demonstrating human viability in the area prior to the glacial maximum. During the glacial maximum itself there is an interesting non-homogeneous distribution of human settlement. The southwestern region, which Cosgrove et al. (1990:63, Fig. 2) describe as a stable ecosystem "characterized by resource patch-richness," and less variable precipitation, has a rich archaeological record of continuous settlement from approximately 30,000 to 13,000 years ago; i.e., it was clearly occupied during the last glacial maximum. The southeastern region, on the other hand, described as an unstable ecosystem characterized by dispersed, unpredictable resources, decreased and unpredictable precipitation, and prone to dust storms (Cosgrove et al. 1990:64, Fig. 2; Jones 1990:290), lacks any evidence for human occupation during the last glacial maximum. Although Jones (1990:290) notes that the drier southeastern region of Tasmania lacks evidence of any occupation older than 6,000 year B.P., this may not be directly pertinent to the argument here, as even the relatively richer southwestern region was deserted after 13,000 years ago. Jones (1990:290) wonders if this was "due to the rapid and catastrophic flooding during this time-period . . . which may have led to the collapse of a well-integrated seasonal pattern of movement, north-south along the valley corridors of western Tasmania."

7.2.c Comparative Synthesis

The archaeological record of the last glacial maximum, as is true with most aspects of the real world, "appears complex and disorderly. Either this complexity is really chaos or it is complex regularity" (Whynne-Hammond 1985:21). As Guthrie (1990a:44) states, although "dramatic contractions and expansions in distribution of many species may at first glance seem random . . . there is a clear pattern in these distributional changes . . . [which] sheds light on the nature of underlying ecological events." Although Guthrie is in fact referring to non-human mammal species, it would be expected that patterns in human distribution may very well reflect variations in environmentally determined distributions of biotic and abiotic resources, since "hunter-gatherer populations are ultimately limited by their environment" (Belovsky 1988:347).

A clear pattern does emerge from the mass of details of spatial and temporal variations in human settlement in the millennia bracketing the last glacial maximum of ca 18,000 years ago (Fig. 7.3b). What Gamble and Soffer (1990b:13) describe as a "very patchy distribution of humans in the glacial world" exhibits three clear distributional trends. First, areas devoid of population correlate with areas believed to have been ice-covered or characterized as polar desert, desert, or arctic desert. This is not strictly a high latitude correlation within the vicinity of ice, but an association with areas characterized by extreme aridity and cold. Thus, such areas include all the northern regions of Europe, the Caucasus of south central Russia, much of South Central Asia, the polar desert areas of western Beringia, and southeastern Tasmania. Although it may be intuitively obvious, Velichko and Kurenkova (1990:Plate 1) classify ice sheets as "territory

Legend for Figure 7.3a and 7.3b

⬯	Ice, whether continental or mountain
⁘	Desert, whether arid or arctic
⬭	Lakes
— — — —	Coastline at glacial maximum
⸬	Southern Tundra-steppes
░	Periglacial steppe and forest-steppe in areas of permafrost
▦	Areas devoid of population at last glacial maximum
▩	Areas with sparse or occasional occupation at last glacial maximum
▨	Areas with no decrease, and/or increase at last glacial maximum
●	Sites dated to last glacial maximum

Figure 7.3 a
Vegetation Zones ca. 18,000 yr B.P.

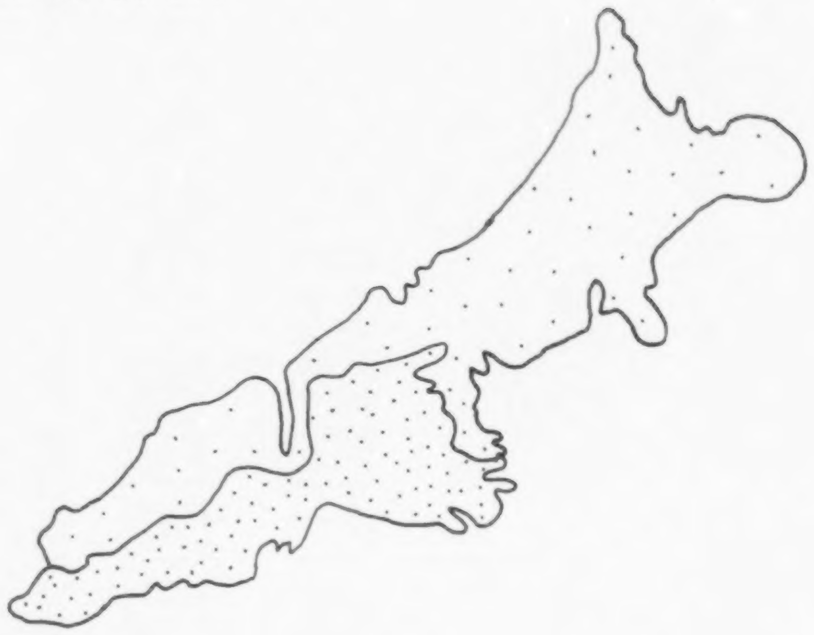
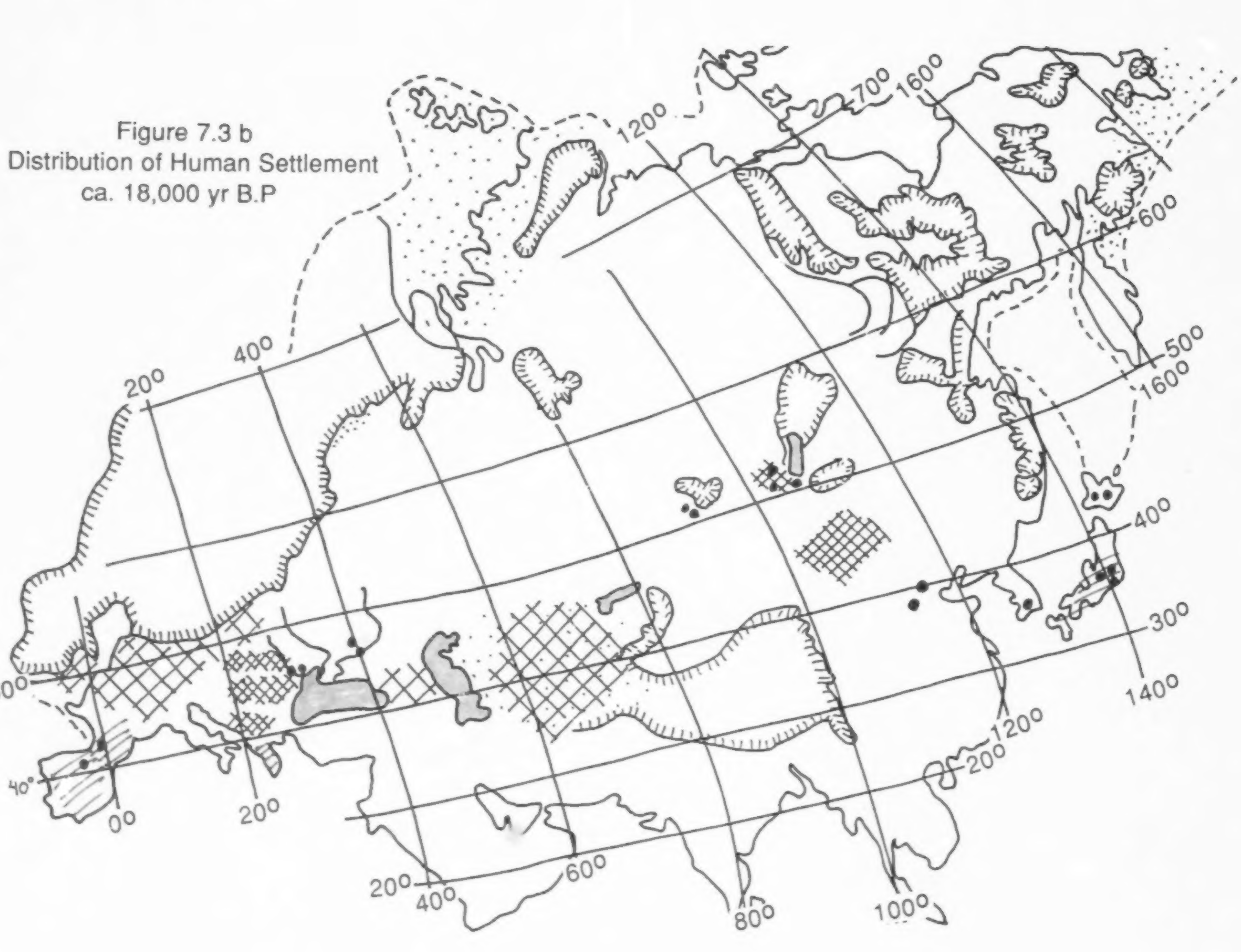


Figure 7.3 b
Distribution of Human Settlement
ca. 18,000 yr B.P


120°
70°
160°
60°
50°
160°
40°
30°
140°
120°
20°
100°
80°
60°
40°
20°
20°
40°
50°
40°
0°
20°

unsuitable for human occupation," and deserts as "territory mostly unsuitable for human occupation."

Although "it is never comforting to deal with negative evidence" (Davis 1990:274), and "archaeologists do not get much pleasure out of demonstrating that something was not there" (Wobst 1990:340), the widespread lack of Upper Palaeolithic sites particularly dated to the last glacial maximum from so many regions in both north and south latitudes suggests that these areas "were apparently depopulated around the LGM [last glacial maximum]" (Gambler and Soffer 1990:13). This pattern may be a reflection of the fact that "climate and consequent environment change affects regional cultural adaptations primarily at their margins" (Snow 1981:101), and that, "other things being equal . . . it is generally true . . . that harsh surroundings restrict man's choice more than moderate surroundings" (Whynne-Hammond 1985:6).

The second indication is in respect to those areas indicating either sparse population or populations that indicate some negative impact associated with the glacial maximum. Again there is not a strict latitudinal correlation. The evidence from this level of occupation plots on a SW to NE trajectory from western Europe to northeastern Asia. Interestingly, this distribution trajectory appears to have paleoenvironmental validity, approximately correlating with the northern part of the southern tundra steppes, which Velichko and Korenkova (1990:Plate 1) classify as "territory suitable for human occupation." Many areas that saw a decrease to sparse or intermittent occupation (e.g., southeastern Europe, the central Russia plain and perhaps the sites west of Lake Baikal in Siberia) are located just north of the southern tundra steppes in the northern tundra steppes, classified by Velichko and Korenkova

(1990:Plate 1) as "of limited suitability for human occupation." The rest are located in rugged mountainous or extremely arid areas, e.g., the Balkans, the southeastern plateau region of South Central Asia, Mongolia, and southwestern Tasmania. The Diukhtai sites may appear to be an exception but the question of the dating of these sites has already been discussed; i.e., it is considered most likely that the culture dates to ca. 14,000 to 12,000 years ago. In any case Diukhtai Cave is found on a south branch of the Aldan River within a "low and middle elevation" zone considered "suitable for human occupation" by Velichko and Korenkova (1990:Plate 1) and not within the "unsuitable zone" to the north.

Third are those areas that experienced no settlement hiatus or decrease and in fact may have experienced increases in population during the last glacial maximum. Such areas are all found south of 45^0 N latitude in relatively rich diverse environments, e.g., southwestern France, Spain, Italy, China, and Japan.

Further correlations relate to the settlement loci of the successful adaptions (i.e., the second and third types described above). The second type, with sparse or variable population but clearly some adaptational success, appears to be oriented around river valleys, perhaps for the purpose of access to more predictable, albeit lineally distributed resources. This pattern is evident on the Central Russian Plain and southwestern Tasmania, and also may have been the case for the sites on the Yenesei, Angara, and Lena rivers west of Lake Baikal and perhaps Diukhtai Cave on the Aldan River. The third type of occupational area correlates with both riverine sources as above, plus coastal areas (e.g., southwestern France, Spain, the Epirus region of Greece, and Japan).

What do these correlations indicate? One approach would suggest a link between such correlations and risk minimization by human populations. Madeyska (1990:25) suggests that an increase in settlement concentration on seacoasts and rivers occurs with an increase in aridity. This distribution would not necessarily mean that water was the overriding factor, although a lack of dependable water sources is clearly a limiting factor in arid areas (Ames 1987; Butzer 1988:200; Madeyska 1990:25). Nor would it necessarily imply actual utilization of waterborne resources, e.g., fish, although this does appear to be the case in Spain (Strauss 1990:104). Instead it may be that resources are relatively more predictable and more diverse near river and coastal areas; as they are certainly less predictable, less productive, and less abundant in drier areas (e.g., Butzer 1988:201). Furthermore, river valleys and coastal areas may act as natural travel corridors for both animals and humans.

We might consider that type three occupations were successful because ultimately in those areas resources were inherently both more predictable and more diverse. The relative success of type two occupations may have been the result of development of strategies for dealing with unpredictable environments, e.g., mass capture techniques, storage, and/or extensive mobility. They may have used the most severe areas only seasonally — presumably in the summer months, as for example documented for aboriginal Australia where the cold, rugged, resource-poor highland areas were used as a peripheral zone, occupied only for brief periods in the summer season. That is, as Gamble and Soffer (1990b:13) suggest, the function of areas within type two zones would have alternated, from the use of a region as a core area, to its exploitation as a periphery for logistically organized groups located elsewhere.

It is interesting that the only long-term duration occupation within the harsh environmental conditions of the permafrost zone, often used as a likely high latitude analogy for early North Americans, is in fact an anomaly; that is the famous "tundra dwelling mammoth hunters" of the Russian Plain, viewed as typifying high latitude Upper Palaeolithic adaptations, were 1) not demonstrably mammoth hunters, and 2) not tundra dwellers. In the first case, Soffer (1990:236) notes the extreme difficulty in determining the role of mammoth in the diet because of its extensive use as raw material, fuel, and construction material. Secondly, the environment of the Russian Plain is described by Soffer (1985:174) as periglacial steppe and forest steppe. Furthermore, Soffer (1990:240,249) notes that

> the most significant feature of economies of this area during the LGM is the use of in ground storage . . . It is this practice of harvesting herbivores at their peak abundance (probably late summer - early autumn), storing meat in pits dug into permafrost, and living off the cached resources during the long and resource-lean cold season that permitted . . . [exploitation] of a cold, productive, but fairly unpredictable environment.

Thus far the primary consideration has been the regular availability of food as a limiting factor. Butzer (1988:20[illegible]) notes, however, that a primary limiting factor in higher cold treeless latitudes is availability of fuel. It is likely that a critical limiting factor on those northern steppes was fuel and that the successful adaptation of the human populations of the Central Russian Plains was largely based on the burning of mammoth bone. It should be noted that the above quotes regarding storage refer in particular to groups in the central region of the Central Russian Plain, north of the permafrost border. Other human populations in the south and eastern areas of the Russian plain "did not use these strategies, and may have exploited the resources on hand through group mobility" (Soffer 1990:249).

Thus we see that although the romantic image of Upper Palaeolithic tundra-dwelling mammoth hunters, commonly depicted in the popular press, is intuitively attractive, it is ultimately misleading. It is not representative of the class of phenomena it is purported to exemplify, not even in its own region, much less the entire northern hemisphere; instead it represents an "elaboration in behavior that was rather aberrant for most hunter-gatherers" (Soffer 1990:250).

Scenarios (e.g., Diamond 1987, Fagan 1987) that utilize such an example to represent 'typical' high latitude occupations suffer from the logical fallacy (and inherently unanthropological error) of hasty generalization.

> In seeking to understand and characterize all cases of a certain kind, one can usually pay attention to only some of them. But those examined should be typical rather than atypical. If one considers only exceptional cases and hastily generalizes to a rule that fits them alone, the fallacy committed is that of . . .hasty generalization (Copi 1972:82).

I find this error in logic particularly interesting because of its similarly to other generalizations in anthropology; for example, the traditional use of aggressive male-dominated baboon species as representative of typical primate behavior, when they represent merely one extreme on a continuum. It is believed that baboon behavior was over-generalized to apply to all primate behavior because it conformed to a traditional Euroamerican world view of aggressive, male-dominated, rigidly structured social life (Martin and Voorhies 1975). Similarly, the "mammoth hunters" myth conformed to traditional European expectations of Upper Palaeolithic behavior formed mainly within the context of southwest France.

Regarding the unsuccessful adaptations, i.e., the type one occupational areas described above, it seems probable that unlike populations in other areas, those populations in the most severe environments were unable to deal with unpredictability in resources and/or the ultimate lack of resources. Cosgrove et al. (1990:67), in reference to the contrast between southwestern and southeastern Tasmania, discussed above suggest that "the eastern border of the southwestern geographic zone . . . marked a human behavioral boundary in the late Pleistocene." Perhaps there is a minimum threshold point, i.e., a "human behavioral boundary" at which an extremely rigorous depauperate environment can no longer support even minimal human populations. Although it has been suggested that such areas were actively abandoned, i.e., through actual population movement, for example to refuge areas in southwestern France and the Ukraine (cf. Jochim 1987:322), it is in fact more likely that such groups became locally extinct (Gamble 1984:254). There does however, appear to be indications of possible population movements into some type three areas, presumably from type two areas.

A distinction can be made between areas (types two and three) with continuous settlement during the last glaciation — albeit at varying population densities — and those (type one) with records of discontinuous settlement. The latter experienced what Gamble (1984:248) calls "an ebb and flow model of settlement and abandonment," with settlement in times of climatic amelioration, and abandonment (by local extinction) in times of climatic extremes. Fitzhugh (1972:186) documents a similar "pulsation model" of population settlement and abandonment for the interior of the Labrador peninsula of Canada in ethnographic times and perhaps extending back 5000 years. There is a clear correlation between extremely rigorous environments, characterized by depauperate unpredictable resources, and a lack of human occupation, demonstrating that variations in the distribution of human populations in various parts of the world are not isolated events (Turner 1984:212). The relationship is a straightforward correlation; as the temperature, moisture, and diversity, abundance and predictability of resources decrease, so does the likelihood of human population. The converse relationship, however, is not necessarily true; there is not a clear relationship between abundant resources and likelihood of human occupation. Thus the relationship between environmental conditions and human occupation only has predictive power in limiting environments.

Following from the previous arguments, we might ask, why would, or should, we expect to see human occupation in severe glacial environments ca. 18,000 years ago in North America? Not only is evidence lacking for human occupation in similar areas of extremely arid, extremely cold, environments characterized by low resource productivity, abundance and diversity elsewhere in the world, even in areas that clearly supported human populations just prior to the last glacial maximum; but "even the periglacial package, which our textbooks stress as the ultimate demonstration of Pleistocene human success, often actually failed" (Wobst 1990:334).

Furthermore, Madeyska (1990:33) points out that there are no sites during the last glacial maximum closer than 400 km to the margins of the ice sheets in Europe. On this basis alone, it is unlikely any human occupations would occur in the ice-free corridor during the last glacial maximum. Also referring to the archaeological record of the North European Plain during the last glacial maximum, and possible global correlations, Lynch (1991:270) concludes, "if we knew *nothing* of the archaeology of Beringia, it still would not be reasonable to presuppose a Beringian population before that date." If there were human populations in northwestern North America at the time of the last glacial maximum (which as yet is not demonstrated), the chances are they would have moved or become extinct as populations apparently did in extreme environments elsewhere. Even potential immigrants outside the corridor region, e.g., in Beringia, would have been quite likely to die out. If, on the other hand actual population movement did occur (in these hypothetical populations), such movement would likely have been to more equable and predictable areas to the southwest (Young 1988), not less predictable, more severe ones to the southeast; i.e., the direction of the corridor. On these grounds alone, it is inexplicable that anyone ever expected human viability in the corridor during the glacial maximum — even aside from questions of physical accessibility.

Watson et al. (1984:154) state that "ecological analysis begins with the discovery of covariation between environmental and cultural phenomena." It has been established above that such a covariation existed between extremely cold, arid, depauperate environments and a lack of human occupation. A detailed understanding of the possible causal relationships between culture and environment is the next step (Watson et al. 1984:154); that is, although there is a demonstrated correlation, we still need a mechanism, an understanding of general underlying principles, to explain the relationships between the assorted variables.

As Snow (1981:98) states,

> we have almost no notion of the mechanisms through which climate change led to environmental change that in turn led to culture change. Without an understanding of those mechanisms we have what might be an association, but we

have nothing at all approaching explanation.

Davis (1990:274) makes a similar point when he stresses the necessity of understanding the limiting factors in Upper Palaeolithic adaptations and how climatic changes have affected the subsistence base, as do Gamble and Soffer (1990b:19) in their call for consideration of the logistics of regional abandonment and recolonization. They are all stressing the importance of the search for mechanisms.

According to Dincauze (1987:319),

> in paleoenvironmental reconstruction, investigators must scrupulously define the *mechanisms that link phenomena to processes* if they are to illuminate the relationships between phenomena . . . The observation of a correlation is the *beginning of the search for mechanism; the end is explanation of a relationship* . . . the successful resolution of a research problem requires the *demonstration, not of correlations, but of mechanisms that link observed data with formulated process* [emphasis added].

That is, successful explanation requires the use of more closely reasoned arguments than are generally utilized in anthropological explanations of environmental/cultural interactions (Dincauze 1981:54). To find these mechanisms and develop arguments, we first need to examine general hunter-gatherer adaptations.

7.3 General Principles of Hunter-Gatherer Adaptations

The primary realities of hunter-gatherer existence relate to spatial and temporal variability in resources. Within a particular geographic area the distribution of plant, animal, and water resouces vary according to seasonal, inter-annual, and longer-term fluctuations, primarily of temperature and precipitation (Rowley-Conway and Zvelebil 1989:40). The various aspects of hunter-gatherer demography, adaptive strategy and social structure can be viewed as response variables to environmental structure (Gamble 1986:31; Low 1990:230); that is, the structure of the environment has an impact on virtually all aspects of hunter-gatherer behavior, from economic to social. Additionally, variations in the structure of the environment result in variations in hunter-gatherer response. This variation is not random, but appears to "result from [the] same underlying principles applied to variable ecological conditions" (Gamble 1986:35). These response variables, some termed "buffering mechanisms" in order to emphasize the nature of the relationship between cultural response and an uncertain environment, include such aspects of hunter-gatherer organization as population density, group size, mobility pattern, subsistence type, marriage rules, alliance systems, resource specialization vs. generalization, and storage strategies (Low 1990:230; Halstead and O'Shea 1989:3). Although the complex interrelationships between the variables makes separation difficult, for analytical purposes it is helpful to group them into divisions of spatial, demographic, and social variables (Gamble 1986:35).

7.3.a Spatial Aspects of Hunter-Gatherer Behavior

Gamble (1986:46) stresses the importance of space in understanding aspects of hunter-gatherer variation. Hunter-gatherer spatial organization is adaptively related to the resource characteristics of the environment (Dyson-Hudson and Smith 1978:37) and "the need to physically disperse personnel to exploit both the currently and continuously dispersed resources" (Jarvenpa and Brumbach 1988:612).

7.3.a.1 Settlement Systems

A primary aspect of hunter-gatherer spatial organization that relates to ecological structure as reflected by local resource conditions is the type of settlement system (Perlman 1985:3; Gamble 1986:47). Hunter-gatherer settlement systems can be designated as forager or collector types based on the way they use the environment. As defined by Binford (1980:5), foragers have high residential mobility, lack storage, and utilize an encounter basis approach to gathering food. Collectors, on the other hand, have low residential mobility, store food, and use specially organized food procurement task groups (Binford 1980:10).

These two settlement system types are associated with differing mobility strategies, what Binford (1982:6) calls "tactical mobility," or characteristic patterns of moving about the landscape (Kelly 1983:277) that relate to the spacing and seasonal distribution of resources in the environment (Phillips 1987:174). "Foragers move consumers to goods with frequent residential moves, while collectors move goods to consumers with generally fewer residential moves" (Binford 1980:15); that is, foragers are characterized by residential mobility (Kelly 1983:278).

> The residential mobility system is used by groups of hunter-gatherers when resources are widely scattered and perhaps scarce. The group moves en masse through the exploitive territory; the people 'map on' to their resources by these moves (Phillips 1987:175).

The logistically organized mobility system, on the other hand, is used by collecting groups in areas where resources, albeit highly seasonal, are nonetheless predictable and storable. Phillips (1987:175) makes the important point that although these two types are often viewed as mutually exclusive by many archaeologists, all hunter-gatherers can switch between the two systems as conditions dictate.

7.3.a.2 Mobility

It seems it is not possible to discuss any aspect of hunter-gatherer adaptation without dealing with mobility, as the previous brief discussion of settlement system demonstrates. Mobility as a "positioning strategy"

(Binford 1980:14), in fact, permeates all aspects of hunter-gatherer life at varying temporal and spatial scales. Differential availability of resources in time and space, and low resource density are major determinants of hunter-gatherer mobility (Hassan 1981:56; Hayden 1981a:377). This resource variability is reflected by the wide range in patterns of movement among hunter-gatherers, i.e., from 1 to 60 moves per year over distances ranging from 2.4 to 69.5 km per move (Kelly 1983:Table 1). However, there is a clear relationship between the extent of mobility as measured by frequency and distance covered, and the relative resource richness of the environment (Kelly 1983:214; Gamble 1986:38; Otte 1990:65). Mobility increases as production, diversity, density, and reliability or predictability of resources decreases (Dyson-Hudson and Smith 1978: Fig. 1; Hayden 1981a:378; Green and Perlman 1985:119; Butzer 1988:200), as well as with decrease in temperature and increase in aridity (Low 1990:242). Although many authors have discussed the effect of one or more of these limiting factors it should be noted that impacts on mobility (and many other aspects of hunter-gatherer behavior) appear to increase geometrically when various of these factors are combined. Low (1990:242), for example, notes that while mobility increases with increasing cold or drought, societies are most mobile in environments that are both cold and dry.

The intuitively obvious relationship between limiting factors of the environment and hunter-gatherer mobility, i.e., that the scarcer, farther apart, and more unpredictable resources are, the farther one must travel to encounter adequate amounts of them, casts a somewhat positive light on mobility as an adaptive strategy. Traditionally the advantages of mobility as a means of dealing with environmental variability have been stressed. A consideration of the role of mobility must also, however, consider the costs involved, as measured in energy or time expended in travel (Perlman 1985:35)

Assuming that "the maximum mobility cost a group can absorb from a location is set by the existing transportation technology" (Perlman 1985:3), or lack thereof, then any costs above the maximum threshold require an adjustment in either technology, diet, or location. For example, "residential location must change when the commuting time needed to get to patches of potential resources outweighs resource search and pursuit time" (Kelly 1983:291); that is, it is common to change territory when mobility costs in the new area (and hence energy gain) are anticipated to be less than in the old area (Snow 1981:114). That these costs are in actuality considered by hunter-gatherers is reflected by the !Kung explanation that "they move camp frequently to minimize the distance between 'home' and the available food sources" (Howell 1985:168). The relationships between mobility costs and limits on group size, home range, use of storage, and other variables will be discussed separately below.

7.3.a.3 Range Size

"Range" is a preferable term to "territory" in describing the area utilized by hunter-gatherer populations, as hunter-gatherers are seldom in fact "territorial" in the usual sense of the word. As might be expected, given the relationship between resource richness and mobility, there is a similar relationship between relative resource richness and the size of the range of a hunting and gathering group. Thus we see that range size increases as productivity, diversity, density, and predictability of resources decrease (Butzer 1988:200; Rogers 1969; Minc and Smith 1989:37; Greiser 1985:8), as well as with decreases in rainfall and temperature (Gamble 1986:48). Large range sizes have also been correlated with high latitudes, i.e., "it has been well established that the farther north the location of an inland social group, the larger the size of the support territory" (Brown 1987:365). It is likely that the high latitude/large range size correlation merely reflects the conjunction of several already mentioned limiting environmental factors; i.e., high latitude itself is an associative rather than essential limiting factor. Another suggested limiting factor is dependence on meat; that is, the higher the proportion of meat in the diet, the larger range size necessary to satisfy nutritional needs, particularly if the prey are migratory (Turner 1984:201).

Thus far, only factors that operate to expand range size have been considered. There are simultaneously other factors operating to limit or lower range sizes. The primary limitation on range size is the cost of mobility, discussed above. Estimates of maximum daily activity distances are remarkably similar from disparate sources. Perlman (1985:39) reports a maximum walking distance under 10 miles, suggesting 6 miles as the optimal distance. Six miles, the equivalent to ten kilometers, is the maximum distance cited by most authors (cf. Henneberg and Ostaja-Zagorski 1984:71). Hayden (1981a:379) reports an optimal distance for foraging or collecting of plants at approximately 8 km. He suggests that optimal foraging or collecting distances for women will range between 5 and 8 kilometers, while optimal foraging or collecting distances for male hunters will vary between 10 and 24 kilometers or sometimes 16 and 48 kilometers (Hayden et al. 1987:282). Most of the cases cited for men are in the 10 to 16 kilometer range, with only one larger than 24; and calculation of an average of male foraging or collecting distances is 16.9 kilometers or approximately 10 miles.

Part of the limitation on distance travelled while foraging or collecting is walking speed, which Hassan (1981:54) calculates as 3 km/hr, and the rarity of extending foraging expeditions over more than one day (Hayden 1981a:382). There seems to be a clear upper limit on the distance that can be reasonably covered on a round trip in one day (assuming no transportation aids or animal power). The primary limitation on the distance covered is mobility costs; that is, once the optimum level is crossed "travel and transportation costs increase while food return remains the same" (Hayden 1981a:420), because "the more distant the food resource, the greater the effort required" (Hassan 1981:53). An analysis of mobility costs among the !Kung concluded 10 miles (i.e., 16 km) was the optimum foraging distance because "beyond a certain distance the exploitation of a resource ceases to be profitable" (Hassan 1981:53).

Based on the derived estimates of optimum foraging or collecting distance of between 10 km and 10 miles (i.e., 16 kilometers), maximum group range sizes have been calculated as 314 to 804 km^2, with an absolute upper limit of 2500 km^2, for hunter-gatherer groups without transportation (Winterholder et al. 1988:302; Hayden 1981a:420). The tendency, therefore, for ranges to enlarge owing to environmental conditions is limited by mobility costs restricting the radius of the range to a distance that can be covered round-trip in a day.

The relationship between range size and mobility is obvious, as one goes up, so does the other. It is an inevitable relationship, such that evidence of large range sizes can be taken as evidence of increased mobility (Rigaud and Simek 1990:83). The reasons for this relate to the similar causes of increase in both mobility and range size, e.g., decrease in productivity or unpredictability of key resources, and the relationship between increase in range radius and range area (Table 7.1).

Table 7.1 Relation Between Range Radius and Range Area

Range Radius in km	Range Area in km^2
10	314
12	452
14	616
16	804
18	1018
20	1256
22	1520
24	1809
26	2124
28	2463

$$\text{Range Area} = \pi r^2$$

7.3.b Demographic Aspects of Hunter-Gatherer Behaviour

7.3.b.1 Group Size

There is a well-documented regularity in hunter-gatherer social organization relating to the size and functions of population groupings. Hassan (1981:51) found that hunter-gatherer bands ranged in size from 15 to 50 individuals, with an average of 20 to 30, while regional bands ranged in size from 200 to 800, with an average of 500. Wobst (1974) discusses similar groupings, referring to them as minimum and maximum bands, respectively, while Dennell (1983) terms them subsistence and reproductive groups in order to emphasize presumed functions of the different levels. They are all essentially referring to the same two types of social groupings.

The two types of groups are interrelated, even nested, so to speak, in terms of organization. The relationship between them is clearly expressed in what Gamble (1986:32) calls the first uniformity of hunter-gatherer life — "the principle of fission and fusion." This principle refers to the tendency of most hunter-gatherer populations, particularly in seasonal environments, to alternate between dispersed minimum bands during that part of the year when resources are scarce and/or dispersed, and aggregate into larger maximal bands in seasons of abundant resources.

Alternating group size through the year via the process of fission and fusion is an effective way of dealing with environmental variability. This mechanism does not, however, explain the observed universality in the size of the groups. Most impressive is the consistency of the "magic number" 25 for the number of individuals in a minimum band. Wobst (1976b:170) argues that since minimum bands of 25 are found throughout the northern and southern hemisphere, on four continents, from the tropics to the arctic, and at various population densities,they must be of general adaptive significance.

Various arguments have been put forth to explain the adaptive function of small groups. Many justify small group size in relation to the productivity of the environment. Wobst (1976b:72) cites the high costs of providing for large groups in environments with "non-randomly distributed seasonally and annually varying food resources." Therefore, one would expect a selection for small group size when resources are relatively scarce and dispersed. Perlman (1985:34) specifies the costs involved as specifically being mobility costs, i.e., a small size is adaptive because a small group needs to move less often. The reason a small group has to move less often is that the requirements of providing for fewer people decrease the rate at which the surrounding area is "hunted out" and therefore increase the time between moves, thus decreasing mobility costs. Hayden (1981a:360) further points out that small group size and moving less often is advantageous to women who are often the burden bearers of hunter-gatherer society.

Thus, from the point of view of coping with low productivity and unpredictability, small group sizes are adaptive (Perlman 1985:44; Butzer 1988:200). Hayden (1981a:371) argues that restrictions on size indicate a "smaller-the-better" relationship, and that this minimum group size of hunter-gatherer populations could consist of a single nuclear family. That is, a nuclear family can be an effective subsistence unit, and in addition possesses both sexes, necessary for carrying out daily activities, and is multigenerational, providing for enculturation functions that Wobst (1976b:72) sees as an important role of the minimum band.

If the adaptive forces that select for small group size can be satisfied by nuclear family groups, an explanation is needed for why groups bigger than the nuclear family are so prevalent in the ethnographic record; that is, small size restrictions alone do not explain the magic number 25. Hayden (1981a:371) argues that the reason nuclear families congregate together is because of the unpredictability of hunting. Because of this unpredictability it is necessary to live in groups large enough for effective pooling of resources and the efforts of individual hunting. "It makes sense to maintain groups that can field enough hunters to make at least one kill per day highly probable" (Hayden 1981a:371). Among the !Kung only one day in four is productive for an individual hunter, thus with four to eight families in a group, meat is likely every other day (estimating that eight families supply eight hunters, two of whom are too old and two of the remaining six who do not hunt every day (Hayden 1981a:374).

> If there were less than 4 families in a group, pressure would be higher on all adult members to hunt every day. When small groups do occur, it appears that generally all able adult males hunt every day (Hayden 1981a:374).

As Hassan (1981:56) states, "if the resource potentials, such as in arctic and desert regions, are too low to permit a group of at least two or three families it is unlikely that the environment could be inhabited at all."

Thus balancing the demands of a need for small groups with the need to pool hunting resources most likely explain the ubiquitousness of the 25 member minimum band. However, the justification behind the grouping of these minimum bands into larger regional or "maximal" bands must still be explained. According to Wobst (1974:152),

> while at least potentially self-sufficient, a given minimum band tends to participate in a larger social network in order to enhance its chance of biological and cultural survival . . . this larger social network *the maximum band* . . . essentially constitutes a marriage network which guarantees the biological survival of its members. The maximum band is,

> thus, a loosely interlocking network of minimum bands maintained through ritual communication and exchange.

The biological and sociological functions of maximum bands are discussed below.

7.3.b.2 Mating Networks

While a minimum band constitutes an adequate subsistence unit, it is not necessarily an adequate reproductive unit. Although some argue otherwise (e.g., McArthur 1976:57), it is generally believed that a subsistence unit cannot exist alone and must function as part of a larger breeding population in order to provide an adequate number of mates (Price 1978:84). Wobst (1974, 1976) proposed the concept of mating networks as a framework for organizing and integrating socio-cultural processes. He was specifically interested in the minimum biologically viable size of such a network, i.e., the minimum population size that would ensure everyone a potential mate. Using computer simulation models of hunter-gatherer groups with varying boundary conditions and restrictions, Wobst (1974) determined minimum equilibrium size ranged from 175 to 475 individuals depending on cultural restrictions and marriage roles. In an open system with no marriage rules other than the incest taboo, a minimum population of 175 is possible; whereas closed systems with more restrictive rules (which decrease potential mates) require a minimum population of 475 individuals. Thus minimum bands of 25 must be part of a larger network of at least 175 to 475 (depending on conditions) to ensure reproductive viability in terms of access to potential mates.

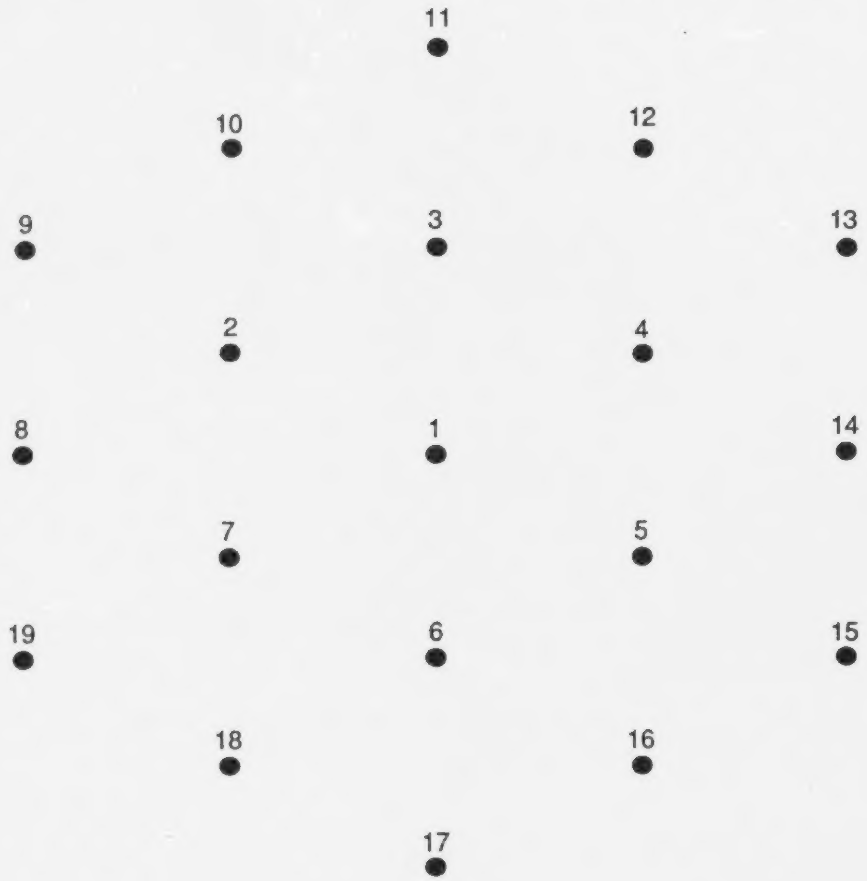
An important part of Wobst's arguments were the assumptions that every minimum band has six neighbors, and that they are hexagonally packed on the landscape (Wobst 1976:50), a maximum packing concept borrowed from geography. Ethnographic data provide evidence that the theoretical concept of hexagonal packing reflects reality; i.e., that bands have between 5.4 and 5.9 neighbors on average (Gamble 1986:52). Wobst numbers the bands out from the center, resulting in a center band surrounded by two "tiers" of neighboring bands (Fig. 7.4). Assuming a 25 person band, one tier of bands, ie. bands #1 to 7, constitutes a population of 175; whereas both tiers, i.e., all 19 bands, are required for a population of 475 (Wobst 1974:159). Due likely to the fact that most human groups do have various restrictive marriage rules, the 475 person (19 bands) population is generally taken as the likely minimum population size. However, as Meiklejohn (1978:70) notes, Wobst's minimum of 475 is possible only under idealized conditions; and in reality the number is often higher.

Further constraints on the ideal number apply if the assumed hexagonal packing is not achieved. If the bands are located in a linear fashion, the ideal pattern of contacts is not possible, resulting in increased costs of maintaining the network (Gamble 1986:53). This is a disadvantage particularly to those groups located on the periphery of such a network (Soffer 1985:472). The increased costs inherent in the maintenance of a linearly arranged network is an important relationship that will be discussed further later.

7.3.b.3 Population Density

Population density is both a demographic and spatial variable. Similar to mobility and range size, discussed above and with which it is intimately interrelated, population density varies according to the relative richness of the environment. That is, population density decreases when productivity, diversity, density, and predictability of resources decrease (Butzer 1988:200; Johnson and Earle 1987:37; Henneberg and Ostoja-

Figure 7.4 Optimum Hexagonal Packing of a 19 Band Mating Network After Wobst (1974:Figure 1). Reproduced with permission of the Society for American Archaeology.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Zagorski 1984:51) as well as with decreases in rainfall and temperature, or increases in latitude, altitude, or extremes of seasonal variability (Flood 1976:40; White and O'Connell 1982:70; Hassan 1981:8; Brown 1987:365).

Various ranges in hunter-gatherer population density have been reported. Hassan (1981:Table 2.1) cites a range from 0.01 to 9.5 persons per km^2. Averaging the data Hassan presents results in a mean of 0.62 persons per km^2, which is not really representative of typical hunter-gatherer population density, as it is skewed by the uncharacteristically high (for hunter-gatherers) value of 9.5 persons per km^2 recorded for the Haida of the Northwest Coast. The distribution of Hassan's data (1981:Table 2.1) reveals that over 50% of groups reported have population densities less than 0.08p/km^2 and over 80% have densities less than 1p/km^2. This pattern is undoubtedly the basis for the common assertion that "typical" hunter-gatherer population density ranges between 0.1 to 1 p/km^2 (cf. Winterholder et al. 1988:302).

Further observation of reported population density values reveals that other than the California acorn gatherers, all hunter-gatherers with population densities greater than 1 person per km^2 are characterized by reliance on coastal maritime resources (Hassan 1981: Table 2.1). Thus we might expect densities greater than 1p/km^2 to indicate productive environments with abundant predictable resources. At the other end of the scale, population densities of less than 0.06p/km^2 have been suggested as indicating relatively unproductive environments (Perlman 1985:37). Reported values from high latitude and high elevation groups range from 0.01 to 0.08 p/km^2 (Moran 1982:112; Hassan 1981; Table 2.1) and values from deserts and semi-deserts range from 0.01 to 0.04 p/km^2 (Bowdler 1981:107; Johnson and Earle 1987:32). Additionally, although Hassan's (1981:Table

2.1) review of 40 hunter-gatherer groups lacks any with population densities less than 0.01p/km^2, lower densities have been reported from exceptionally sparse environments. Rogers (1969:33) reports densities of 0.006/km^2 for Cree groups in Quebec, and Wobst (1976:50) cites "northern hunters" as occurring at densities as low as 0.005 p/km^2.

Population density interrelates with and has an impact on other variables of hunter-gatherer life. As population density goes down, range size necessarily goes up. The independent variable in the relationship is group size, which remains constant (Rogers 1969:33) as either density or range size change in reaction to environmental constraints. Savage (1990b:350), for example, demonstrated the predicted relationship between population density, band size, and regional range size of late Archaic groups in the southeastern United States. Furthermore, Grimes et al. (1984:170) argue that low population densities favor the development of open mating networks, and an absence of distinct cultural and stylistic boundaries.

7.3.c Social Aspects of Hunter-Gatherer Behavior

Gamble (1986:54) describes information strategies and alliance systems as social variables of hunter-gatherer existence. Information, particularly about the environment, plays a very important part in hunter-gatherer adaptations (Butzer 1990:193; Gamble 1986:56). The mating network that unites dispersed minimum bands that make up the maximal or regional band, "also serves as an information network that can provide each subsistence group with knowledge about their neighbors and their regional, as opposed to local, environment" (Savage 1990b:333). Thus information exchange fills economic, demographic, and social needs; it keeps groups informed "on the availability and location of resources and helps distribute them advantageously across the landscape" (Soffer 1985:435). Information generally flows along social networks with ritual gatherings playing an important role in bringing people together for information exchange, mate selection, and other interactions (Bowdler 1981:109).

Alliance systems, generally formalized through exogamous marriage, trade, or spouse exchange, act as insurance policies for inhabitants of high risk, unpredictable environments (Gamble 1986:54). Information transmitted via various social mechanisms helps hunter-gatherers cope with uncertain environmental conditions and pools subsistence risk over large areas (Gamble 1986:338; Soffer 1985:435).

7.4 Hunter-Gatherer Adaptation in Marginal Environments

Arctic and desert ecosystems are the most marginal environments of the present day. They are also the closest analogies to marginal glacial environments. A consideration of the primary characteristics of arctic and desert ecosystems is presented here to build the groundwork for an analysis of the viability of marginal environments, such as were reconstructed for the ice-free corridor.

7.4.a Environmental Structure: Flora and Fauna in Arctic and Desert Ecosystems

Ecosystem production, as measured by primary production and primary biomass, serves as an effective means of comparing different environments. Primary productivity, "the amount of energy in vegetation remaining from the process of photosynthesis after respiration" (Kelly 1983:283), as measured for "a given unit of land surface for a given unit of time" (Barbour et al. 1980:123), is dependent on temperature, water availability, soil nutrients, and soil texture (Moran 1982:73). Temperature and precipitation are generally seen as the critical limiting factors in productivity of the environment. Moran (1982:113) states "tundra and desert ecosystems share similar problems; the crucial difference is that one ecosystem is limited by water availability, the other by extreme cold." Although it is often simpler to comprehend the effects of limiting factors when considered singly, the interrelatedness of temperature and precipitation, along with others, e.g., nutrient availability and length of growing season, must be recognized.

7.4.a.1 Arctic Environments

The almost universally cited values (e.g., Hassan 1981; Gamble 1986) of 10 to 400 g m^{-2} yr^{-1} with an average of 140 g m^{-2} yr^{-1} for tundra ecosystem primary productivity appear to derive from Whittaker and Likens (1975) who reported them as indicative of the range of tundra and alpine ecosystems. Sources referring strictly to arctic tundra in fact never report values greater than 200 g m^{-2} yr^{-1} (e.g., Muc 1972:126; Barbour et al. 1980:490). Furthermore, examination of vegetation types within tundra reveal values between 20 to 110 g m^{-2} yr^{-1} for sedge meadow and shrub tundra, and as low as 3 to 20 g m^{-2} yr^{-1} for high arctic polar desert (Muc 1972:126; Bliss et al. 1973:369; Bliss 1984:17; Walter 1979:250; Henig 1990:76). Thus, 200 g m^{-2} yr^{-1} should be seen not as typical for tundra primary productivity but an upper limit. How much of the limit on production is due to extreme cold, e.g., through suppression of decomposer activity and thus available nutrients (Barbour et al. 1980:490), and how much to decreased solar radiation and short growing season is not clear. What is apparent, however, is the effect low primary productivity has on tundra biomass.

Primary biomass is the "total amount of standing plant material present in a region at a particular point in time" (Kelly 1983:283), as measured by "weight of vegetation per unit area" (Barbour et al. 1980:172). Primary biomass usually includes only above ground plant matter and is "for the most part inedible to humans" (Kelly 1983:283). A commonly cited estimate for tundra primary biomass is 600 g/m^2 (Barbour et al. 1980:Table 11-2; Kelly 1983:Table 3). Again this number is apparently derived from Whittaker and Likens (1975), and refers to tundra and alpine environments. Values for primary biomass from Truelove Lowland, Devon Island, an area whose vegetation is considered more representative of the Low Arctic than the High Arctic in which it is in fact located (Bliss 1977:8) range from 97 to 359 g/m^2 with an average of 248 g/m^2 (Svoboda 1972:157). Primary biomass values from polar desert areas range from 0 to 70 g/m^2, with an average of 20 g/m^2 (Barbour et al. 1980:Table 11-2; Svoboda 1972:157).

The low primary biomass inevitably has a negative effect on the secondary biomass, the fauna. Especially for animals larger than 10 kg "ecological studies demonstrate that the maximum environmental biomass of these prey animals is a function of plant productivity" (Belovsky 1988:339). For smaller animals the relationship is complicated by the importance of insects in the food chain of small mammals and birds (cf. Rogers et al. 1988). Estimates of animal biomass for arctic ecosystems range from 400 to 800 kg/km^2; the latter figure referring in particular to caribou herd areas (Bliss 1984:17; Hassan 1981:14; Kelly 1983: Table 3). Hayden (1981a:349) considers this level "medium" as compared to biomass levels elsewhere in the world. In absolute terms, i.e., per square kilometer, the animal biomass of the arctic is low as compared to all other major biomes. Although the ratio of animal biomass to primary production is higher in the arctic than e.g., a tropical forest, this ratio primarily reflects differences in accessibility of primary production (Kelly 1983:287). As the point of examining biomass levels is in relation to impact on human survival, values per area seem more appropriate. On these terms, terrestrial animal biomass values in the arctic are clearly low, reflecting the ability of low temperature ultimately to decrease faunal density.

In addition to a decrease in faunal density, arctic ecosystems are marked by a decrease in faunal diversity (Hassan 1981:179; Kelly 1983:Table 5). Meltzer and Smith (1986:6) note that although there are fewer overall species in high altitudes, there are higher numbers of individuals per species. Low species diversity results in great year to year variation and unpredictable and extreme fluctuations in faunal densities (Rowley-Conway and Zvelebil 1989:42). This is the case even for caribou, who are highly adapted to the long arctic and subarctic winter through their preference for and the ability to survive on lichens (Russel and Martel 1984:125).

The extremely low temperatures and highly seasonal nature of the arctic ecosystem thus cause considerable variations in resource availability, both temporally and spatially (Meltzer and Smith 1986:6). "Most high latitude areas have markedly uneven resource distribution with concentrations along watercourses and coasts" (Rowley-Conway and Zvelebil 1984:42). All these factors combine to make the arctic ecosystem a highly unpredictable environment. In this context, it is interesting that recent northern peoples extensively use marine as opposed to highly unpredictable terrestrial resources.

7.4.a.2 Desert Environments

Primary production is lower in desert environments than all other world biomes (Barbour et al. 1980:244). The primary factor limiting production in deserts is clearly water availability, as the "relationship between production and annual rainfall is nearly linear at values below 500 mm" (Barbour et al. 1980:255). Although the "environmental factor most directly correlated with production is water" (Barbour et al. 1980:255), it is not the only pertinent variable. For example, an ecological study of a semiarid *Artemisia* dominated community in Washington state demonstrated the importance of temperature and nutrient availability in determining production rates. Rickard and Vaughn (1988:174) estimated that variations in soil temperature and nitrogen content accounted for 77% of the variability in production (within the limits imposed by water availability). Other important factors are soil organic matter and windiness (Moran 1982:174).

The most commonly cited values for primary productivity from desert and semi-desert environments are 10 to 250 g m^{-2} yr^{-1}, with an average of 90 g m^{-2} yr^{-1}. Values of 0 to 10 g m^{-2} yr^{-1}, with an average of 3 g m^{-2} yr^{-1} are reported for extreme rock and sand deserts (Barbour et al. 1980:Table 11-2). An examination of other sources reveals somewhat higher numbers, with a range of 70 to 600 g m^{-2} yr^{-1} and average of 250 g m^{-2} yr^{-1} for semi-deserts and a range of 10 to 280 g m^{-2} yr^{-1}, and average of 130 g m^{-2} yr^{-1} for deserts (Walter 1979:255: Moran 1982:176; D.S.G. Thomas 1989:47; Rickard and Vaughn 1988:174). No new estimates for production in extreme deserts were encountered. Though these values are higher than those cited in Barbour et al. (1980:Table 11-12), they are still lower than values for non-desert environments. These low primary productivity values are reflected as well by low values for primary biomass, i.e., the above ground plant material.

Values of primary biomass in desert environments range from 100 to

4000 g/m^2 with an average of 700 g/m^2 for desert and semi-desert areas, and 0 to 200 g/m^2 with an average of 20 g/m^2 for extreme desert areas (Barbour et al. 1980: Table 11-2). These values are derived from Whittaker and Likens (1975); neither more recent, nor more vegetationally precise, estimates were encountered.

Although the primary biomass values for desert and arctic environment are comparable, i.e., 700 g/m^2 and 600 g/m^2, respectively, the primary biomass of deserts is often seen as relatively more accessible to both humans and large herbivores than that of tundra environment, and in particular, more than other demonstratably more productive environments, such as various forest types (Kelly 1983:286). Although this conclusion may at first seem counterintuitive, it should be noted that desert production is low because of the low density of plants, not that individual plants are low in production (Barbour et al. 1980:534). Kelly (1983:286) states that "in areas of low primary biomass, . . . less energy is invested in plant structural maintenance and growth and more in reproductive structures (seeds)." However, although generally speaking it is true that above ground primary production of deserts is potentially more accessible and thus more useful to humans and large herbivores, this is not so for example in *Artemisia* dominated communities. Rickard and Vaughn (1988:174) note that while total primary productivity values for the sagebrush-bunchgrass community averaged 550 g m^{-2} yr^{-1}, 480 g m^{-2} yr^{-1}, of that amount (i.e., 87%) consisted of woody stems of the sagebrush. The edible portion of the sagebrush available to herbivores, i.e., the leaves, accounted for 10 g m^{-2} yr^{-1}, or only 2% of total sagebrush above ground production (Rickard and Vaughn 1988:174). This analysis demonstrates that not only are all deserts relatively depauperate in terms of usable vegetation, but the particular type of semi-desert vegetation often reconstructed as typical of full- and late-glacial environments is particularly low in accessibility of primary production.

As is true with arctic environments, the low primary biomass of desert environments is reflected by low levels of secondary biomass. In addition to the aspect of nutritional accessibility of primary biomass, discussed above, animal biomass levels are suppressed owing to much of desert plant production occurring below ground, making it physically inaccessible (Moran 1982:174). A value of 500 kg/km^2 is often cited for the secondary biomass desert and semi-desert environments (Kelly 1983:Table 3). Examination of values cited in D.S.G. Thomas (1989:47) and Hassan (1981:Table 2.3) reveals a range of 13 to 1300 kg/km^2 with an average of 393 kg/km^2 for steppes and semi-deserts, a range of 190 to 600 kg/km^2 with an average of 330 kg/km^2 for deserts, and a range of 0.3 to 17 kg/km^2 with an average of 7 kg/km^2 for extreme deserts. These values are comparable to, or lower, than those reported for arctic environments; and with the arctic values represent extremely depauperate animal biomass as compared to temperate forest (e.g., 700 to 3400 kg/km^2) or savanna (e.g., 5000 to 24000 kg/km^2) values (Hassan 1981:Table 2.3).

As in the Arctic, the low desert fauna biomass and thus density are accompanied by decreased species diversity. Kelly (1983:Table 5) describes deserts and semi-arid environments as characterized by medium species diversity, but supporting mainly animals with small to medium body size, e.g., coyotes, rabbits, mice, voles, and squirrels (Rogers et al. 1988:223). In reference to a semi-arid shrub-steppe environment, Rogers et al. (1988:223) state,

> the problems of existence in the shrub-steppe are clearly exhibited by the relative sparseness of animal life . . . the nesting passerine birds and microtine rodents, which are usually found in wide variety elsewhere, are represented in the shrub-steppe by only a few species. More importantly, while there is a wide range in body size for shrub-steppe animals, the balance between large animals and small animal biomass is tilted markedly towards the small ones such as rodents, and insects.

In general, ungulate populations in desert and semi-arid areas are very sparse (Bay-Peterson 1978:126). Rogers et al. (1988:223) note that while deer and elk are present, they are vastly outnumbered by smaller animals and in addition require larger home ranges than in mountain forested regions, reflecting the sparseness of the vegetation. A wildlife ecology study in the Hindu Kush area of South Central Asia reported that "grazing by large herds of ungulates will . . . tend to increase shrubs over grasses in marginal environment" (Davis 1990:272), and thus reduce the quality of pasture. Therefore, in marginal environments, the animals themselves play a role in determining ultimate faunal density.

Resources tend to be relatively unevenly distributed in desert ecosytems. The moisture-based continuum of vegetation, ranging from bunchgrass and shrubs through widely spaced xerophytic and halophytic vegetation to areas completely lacking in vegetation except where precipitation collects (Moran 1982:147; D.S.G. Thomas 1989:5), is paralleled to some extent by the animal life these varied micro-environments support. In general, however, faunas are not dense "except in marshes and lakes at breeding and nesting time for water fowl and spring and fall fish runs" (Fowler 1989:xxviii). The low faunal diversity leads to a decrease in resource stability, ultimately resulting in an environment characterized by high instability and wide fluctuations in the resource base (Hayden 1981a:418). It is not surprising that "for much of history and for many human races, [deserts] have been areas to avoid" (D.S.G. Thomas 1989:2).

7.4.b Mechanisms for Coping with Risk and Uncertainty

Marginal environments are characterized by low faunal diversity, resource fluctuations, and an unstable unpredictable environment. Rowley-Conway and Zvelebil (1984:40) delineate three scales of resource fluctuations: 1) seasonal, variations that occur within one year, 2) interannual, between year variations, and 3) long-term, extending over a generation or more. Many anthropologists feel the key to understanding hunter-gatherer adaptations to marginal environments lies in determining the mechanisms used for dealing with risk and uncertainty caused by fluctuations in both resources and the physical environment on these scales.

Cashdan (1990:1) defines risk as unpredictable variation in environmental and economic conditions, and uncertainty as a lack of information about these risks. Risk, therefore, results in uncertainty and not vice versa (as might be expected assuming an intuitive definition of risk). Halstead and O'Shea (1989:3) delineate four "buffering mechanisms" or possible cultural responses to variability: 1) mobility, 2) diversification, 3) storage, and 4) exchange. These mechanisms may be utilized singly or in various combinations to lessen, absorb, or protect against the unpredictability caused by risk and uncertainty. There are, however, limitations as to how these options for responding to risk may be used, as some combinations are complementary, while others are incompatible. For example, while the combinations of mobility and diversity, or storage and exchange serve to mutually reinforce each other, mobility may "preclude the effective use of storage" (O'Shea and Halstead 1989:124).

7.4.b.1 Mobility

The advantages of mobility for dealing with dispersed and variable resources have already been discussed; i.e., that low productivity and predictability of food and water resources require high mobility (Butzer 1988:200; Gamble 1986:40). Mobility can be seen as a way of moving away from scarcity and a means for exploiting resources found elsewhere (Halstead and O'Shea 1989:3; Rowley-Conway and Zvelebil 1989:44). Thus, mobility is a likely response to extreme conditions (Minc and Smith 1989:26). Furthermore, mobility can be on larger or smaller scales, corresponding to the amplitude of environmental variability to which the mobility is a response; that is, mobility as a buffering mechanism can range from day-to-day mobility to the emigration of entire populations.

7.4.b.2 Diversification

Diversification as opposed to intensification is a generalist strategy. While diversification implies inclusion of a broader variety of resources, intensification implies specialization on just a few resources, perhaps only one or two items. "Strongly seasonal or climatically uncertain or unpredictable environments will select for broader environmental niches" (Meltzer and Smith 1986:8). Such environments require the flexibility that diversification allows.

Specialization strategies rely on "boom and bust" taxa and are therefore extremely vulnerable to environmental perturbation. Climatic and biotic variability give specialized systems long-term evolutionary liability, which is why specialists are uncommon (Metzer and Smith 1986:8). Generalized strategies are found everywhere except in low diversity ecosystems with abundant individuals of a single taxa (Meltzer and Smith 1986:9). That is, specialization is often not a feasible option, except in areas where resources, though low in diversity, are nonetheless predictable and abundant (Minc and Smith 1989:37). The modern northern tundra caribou hunters, for example, live in a low diversity environment that provides sufficient biomass to allow specialization. The ethnographic evidence indicates "that specialized caribou hunting is quite viable, although it requires high mobility and fluidity in the social system to reduce search and handling costs" (Meltzer and Smith 1986:12). Even the Plains bison hunters, though often viewed as specialists, were not in fact entirely specialized (Nicholson 1988:358).

> Even the Cheyenne, quintessential Plains bison hunters, hunt antelope, deer, elk and wild sheep, as well as gathering 8 to 10 species of wild root crops, 16 varieties of fruit, and 12 to 15 vegetable stalks and buds (Hoebel 1960:60-64, cited in Meltzer and Smith 1986:8).

Though Halstead and O'Shea (1989) appear to view only the generalist end of the diversification-intensification continuum as a possible buffering mechanism, intensification also can be seen as a behavioral response to stress (Soffer 1985:351). The relatively predictable and abundant nature of caribou that made the northern hunter specialization possible should not be taken to imply their environment was lacking in risk and uncertainty. The adaptation can be seen as a comparatively unique response to particular environment conditions. Supporting intensification as a response to stress, Winterholder et al. (1988:386) argue that in risk avoidance situations, "generalizing a particular strategy (e.g., by including more prey types) may increase rather than reduce the chance of a shortfall" through an increase in average foraging efficiency costs.

7.4.b.3 Storage

Storage of resources is a risk reducing mechanism implemented in response to gaps in the subsistence cycle (Rowley-Conway and Zvelebil 1989:40). The use of storage "is an obvious response to severe environmental constraints which prohibit predictable food procurement on a daily basis" (Greiser 1985:119). Storage balances seasons of plenty against lean seasons by extending the period of utility of a resource (Halstead and O'Shea 1989:4; Rowley-Conway and Zvelebil 1989:44). In particular, storage appears to be a critical part of adaptations "which are primarily dependent upon large mammal hunting and fishing and where alternative resources are scarce" (Gamble 86:37), and in environments characterized by extreme seasonality (Minc and Smith 89:37).

The obvious advantages conferred by the preserving and storing of food "must be weighed against other factors, including increased work efforts and the restrictions of cartage imposed by a nomadic life" (Hayden 1981a:387). Storage strategies involve large labor and time investments (Hayden 1981a:419). First, technologies have to be developed that enable maximization of the harvest of a resource available for a limited period of time, e.g., drive lanes. Second, there is much labor involved in the actual processing and preservation of resources, e.g., by smoking, drying, pounding and grinding, and the manufacture of containers or other storage facilities (Rowley-Conway and Zvelebil 1989:50). Howell (1985:184) argues that in the arctic "freezing solves the storage problem for much of the year." Actually it solves merely the problem of preservation. Storage in suitable containers and protection from the elements and animals are still necessary considerations. The development of preservation and storage technology is crucial. Without technology that can produce a surplus, there is nothing to store; without preservation, food is useless (Rowley-Conway and Zvelebil 1989:49). It "makes no sense to optimize exploitation of a resource if a lack of [appropriate technology] is likely to cause most of it to spoil or be abandoned" (Snow 1981:115). Because of the extensive labor investment

> it is thus likely that most band societies avoided food storage except in the most stringent circumstances . . . Regular and long-term storage of food involves a considerable outlay of effort and time and only occurs where the environment and population density absolutely require it. Highly seasonal areas and periodically dense resources constitute the major prerequisites (Hayden 1981a:419).

Thus, though storage can act as a buffer against risk and uncertainty, its use is more likely in predictable rather than unpredictable environments. This conclusion suggests "that environmental predictability may limit what is available to be stored" (Low 1990:24). For these reasons, storage cannot be considered a universally viable option.

Further restrictions on the use of storage relate to the restrictions the use of storage places on mobility and vice versa. If one is highly mobile, the problem is access to stored resources cached earlier at previous locations. On the other hand,

> commitment to use of stores, even when potentially available, means that flexibility in regional positioning be greatly reduced. This is not a problem if a sufficient amount of food can be put away to last through a period of resource shortage and if a reliable food supply can be anticipated after that period of shortage ends (Kelly and Todd 1988:238).

However, if food sources are unpredictable, a "group attempting to rely on storage may have found itself in an essentially barren resource area with little time in which to locate alternative food resources when stored supplies ran out" (Kelly and Todd 1988:238). Thus mobility and storage are in large part mutually incompatible and a choice must be made between them (Rowley-Conwy and Zvelebil 1989:47).

7.4.b.4 Exchange

Exchange operates "as a functional equivalent of mobility — moving food instead of moving people" (O'Shea and Halstead 1989:124). Exchange is possible because while hunter-gatherers need to overcome not average but extreme conditions, the worst likely case may not occur. This situation results in a surplus, and it is surplus that makes exchange possible (Rowley-Conwy and Zvelebil 1989:45). Exchange is embedded in social relations and indeed is often termed social storage because exchange is "effected through widespread kinship and social ties between groups" (Minc and Smith 1989:30). Exchange can then be seen as a social mechanism for evening out variation (Rowley-Conwy and Zvelebil 1989:44). As a buffering mechanism exchange works best in regionally heterogeneous environments in terms of spatial and temporal variability; it does not work if failure is on a regional scale (Rowley-Conwy and Zvelebil 1989:50); that is, if everyone does well or everyone does poorly, sharing is of little advantage (Winterhalder et al. 1988:386).

7.4.c Hunter-Gatherers in Marginal Environments

Although all hunter-gatherers encounter periods of stress, the "frequency and severity of these periods of stress seem to increase as resource diversity, density and stability decrease" (Hayden 1981a:413). It is in such resource poor areas that "times of hardship are most frequent, most severe, and most often result in starvation" (Hayden 1981a:420). Hayden (1981a:Table 10.21) reports the following nutritional conditions for hunter-gatherers in marginal areas: Netsilik Eskimo, "very harsh, 10% mortality from starvation every 2 years"; Copper Eskimo, "famine not uncommon"; Mistassini, "food a constant problem, many starvation cases"; Kutchin, "near starvation in spring"; Great Basin Numa, "starvation common"; and Western Desert Aborigines, "semi-starvation at times of first rains."

It is interesting to note the seasonal nature of much of the scarcity. It has been well established that late winter and early spring are commonly the leanest period for hunter-gatherers. Eidlitz (1969:120), referring to such periods in the circumpolar area, states that they are "likely to occur regularly almost everywhere during the late winter and spring, when food stores are exhausted and the new fishing or hunting season had not yet started." Speth and Spielman (1983:2) also report that late winter and spring are "often times of recurrent food shortage, hunger, weight loss and starvation." They attribute these lean times to the general unavailability of plant foods at this time of the year and the lean character of the available fauna.

This time of the year represents the most important variability on a seasonal scale. When reference is made to hunter-gatherers coping not with average, but with worst conditions, it is this relatively depauperate winter "bottleneck" that is being alluded to. Though much is written regarding the "affluence" of hunter-gatherers, many groups, particularly in marginal areas, suffered severe nutritional stress, if not chronically, at least seasonally.

Hunter-gatherers in marginal areas utilize a combination of general processes of hunter-gatherer adaptation plus mechanisms for dealing with their uncertain and stressful environments. The operative environmental factors in marginal environments (low productivity, low temperature, high aridity, low species density and diversity, and high unpredictability) elicit a complex of related responses by resident human groups.

There is a demonstrated correlation between low environmental productivity and increase in importance of hunting, particularly in cold areas (Belovsky 1987:53; Kelly 1983:296; Hayden 1981a:357). Due to the scarcity of plant foods, they are important to human subsistence only indirectly through the food chain (Gordon 1975:31). Related to increased dependence on fauna for subsistence is the association between low primary production and increased percentage of food acquisition by men (Belovsky 1987:57). Since at very low levels of productivity most food acquisition is done by males, the number of men place a limit on the food production capabilities of the group.

The correlation between marginality of environments and increased mobility on varying scales has already been mentioned. Hayden (1981a:377) notes that the frequency of residential mobility of groups in marginal areas ranges from two to three days (e.g., the Guayaki) to two to three weeks (e.g., the Hazda) to one month (e.g., the Copper Eskimo), as opposed to two to six months or longer for groups in less marginal areas. Longer term mobility is demonstrated by the Nuataqmiut, who in bad years had to leave the area entirely, or die out. There were no alternative resources, and all their neighbors were in just as bad a situation, so mobility in the form of emigration was the only answer (Burch and Correll 1972:46).

Furthermore, the increased dependence on fauna can in itself require increased mobility. Ungulates, the most likely prey of humans, tend to be highly gregarious and mobile species which "because of herd size and fodder conditions must often migrate great distances to sustain themselves in open vegetation" (Straus 1990:330). If such ungulates, e.g., caribou, bison, and wild horse, were to be exploited across even part of their range, a high degree of residential mobility and displacements over large territories would be required (Straus 1990:330). In addition, faunal density levels can effect human mobility via the impact of increased mobility costs. Kelly (1983:296) explains high winter residential mobility among the Netsilik as related to the low probability a hunter will catch a seal at a particular breathing hole; "since an area can be hunted out quickly, the distance threshold where commuting time outweighs the resource search and pursuit costs . . . is reached at a short distance" and thus selects for increased residential mobility.

In contrast to the above arguments, Kelly (1983:212), points out that low productivity environments may alternatively result in fewer residential moves, but this is only the case if a storable resource is present. The inland Eskimo of Alaska, for example, were apparently able to deal with the potential incompatibility of mobility and storage. Minc and Smith (1989:36) report that "scheduling conflicts between storage and seasonal mobility were circumvented by caching carcasses near kill-sites and retrieving them throughout the winter."

As expected, group size decreases with increased environmental marginality. Minimum band sizes in marginal areas are small, with group sizes in some areas as small as one to two families or 15 to 16 people, e.g., among the Mistassini and Guayaki (Hayden 1981a:Table 10.7; Hassan 1981:179).

Furthermore, hunter-gatherers in marginal environments are characterized by both low population density and large home range sizes. Rogers (1969:27), for example, argued that it was the paucity of resources in the Hudson Bay lowland area that resulted in "one of the most sparsely populated areas to be found anywhere in the world." Interior Alaskan groups are described as typifying those that require larger ranges in order to survive in relatively scarce environments (Minc and Smith 1989:31). They also, along with hunter-gatherer groups in high altitude areas of the Andes, demonstrate the importance of exchange and alliance to survival in unpredictable environments. In both areas, groups, in addition to being highly mobile, rely on extensive exchange with populations in other areas implemented via flexible alliance systems (Moran 1982:111). Hassan's (1981:185) classification of environmental-demographic patterns includes both inland arctic groups and desert groups within a pattern he describes as likely to be characterized by (in addition to the already mentioned variables) exogamy, patrilocality, and matrilineal, bilateral, or amorphous descent systems; all of which would contribute to flexibility in alliance systems.

7.4.d Modeling Hunter-Gatherer Behavior in Submarginal Environments

7.4.d.1 Introduction

The above review of hunter-gatherer adaptive processes and mechanisms for coping with unpredictable environments provides the basis for modeling hunter-gatherer organization in extremely marginal environments. In this section, general trends in hunter-gatherer behavior are extended past the examples of hunter-gatherers in marginal environments to predict the human response likely in even more extreme conditions, which may be called "submarginal" environments. The result of the modeling will be utilized in the analysis of the submarginal environments characteristic of the ice-free-corridor.

The term "modeling" is used because the application of known principles of hunter-gatherer behavior to nonobserved situations is not a description of reality but a model-building exercise of what might have been. Henneberg and Ostoja-Zagorski (1984:42) define a model as "a logical construct relating a specified number of variables in a specified way." Model building is employed in order to "simplify complex situations, to eliminate unimportant details, and to isolate for special study and analysis the role of one or more interacting elements in a total system" (Getis et al. 1985:3). In building a model, the essential variables and relations are chosen. In this case the essential variables and relations are the spatial, demographic, and social aspects of hunter-gatherer behavior, including in particular, mechanisms for coping with risk and uncertainty.

7.4.d.2 Buffering Mechanisms

As discussed above, Rowley-Conwy and Zvelebil (1989) proposed four buffering mechanisms for dealing with the risk and uncertainty of unpredictable environments. These mechanisms — mobility, diversification, storage, and exchange — vary in potential applicability depending on the scale of resource fluctuation to which they must respond; i.e., seasonal, interannual, or long-term. All the proposed mechanisms are applicable on a level of seasonal variation. However, only mobility, diversification, and exchange are feasible on an interannual scale for hunter-gatherers, and only mobility and diversification are potential responses to long-term variation. The higher the amplitude of variation, the fewer options are in fact available for dealing with it.

The difference between responses to long-term versus seasonal or interannual variation is that

> flexibility rather than forward planning is the answer . . . in times of long-term decline in prey, predators must either, a) decrease population through starvation and/or migration, b) diversify, or c) both" (Rowley-Conwy and Zvelebil 1989:45).

Although they are referring in particular to variation on a temporal scale, the same relationship should hold true for varying amplitudes of variation, whether temporal or spatial, or in terms of a variable such as productivity. Thus we would expect that as an environment becomes increasingly marginal, in terms of all the above factors, fewer buffering mechanisms will have utility. It is likely that in a submarginal environment, storage and exchange cease to be options.

Winterhalder (1986:3) argues that when conditions are bad for everyone there is no advantage to be had in sharing (i.e., exchange); it would be expected that storage would be selected for in such a situation. The use of storage is common in areas characterized by an effective winter temperature less than 15°C, especially in the arctic (Gamble 1986) and is often assumed to be a requirement for all northern survival. Diamond (1987), for example, assumes that any potential human populations in Beringia would have required methods of winter food storage. Minc and Smith (1989:37) do report a type of dispersed physical storage combined with moderate mobility "in periods when the spatial and temporal scale of stress on resources is high" for prehistoric Alaska. However, in submarginal environments with extremely scarce resources, human populations would have to choose mobility over storage because resources would not be abundant or predictable or reliable enough to store. Consequently, when conditions are extremely poor, there simply is nothing to store or exchange.

One of the two remaining potential buffering mechanisms, diversification, though a necessary goal, will be in actuality difficult to attain in submarginal environments characterized by scarce plant resources and low faunal diversity. Thus, of the four buffering mechanisms proposed for dealing with the risk and uncertainty of unpredictable environments, only one is actually an option. For hunter-gatherers in submarginal environments, mobility is the principal mechanism for ensuring survival.

7.4.d.3 Spatial and Demographic Factors of Hunter-Gather Adaptations to Submarginal Environments

Given the above constraints, what hunter-gatherer processes might be expected in submarginal environments? It is probable that settlement patterns in extremely marginal environments would resemble Binford's (1980) foraging system; that is, they would operate by sending out surveillance hunters who, once successful, would return, and then the entire group would move to the site of the kill (Binford in Moore 1989). They also would be characterized by high residential mobility, which is advantageous when resources are widely scattered and perhaps scarce, and thus require coverage tactics (Phillips 1987:175).

Minimum bands would be expected to move between the centers of foraging areas (Kelly 1983:291), what Binford (1982:10) refers to as a complete radius leap frog pattern. Binford (1982:10) expects such a pattern of movement to be common in "high biomass areas where resources are exploited in proportion to their encounter frequencies." Kelly (1983), however, notes that high mobility in general is a characteristic of both low and high biomass environments. It may be that the important factor is "exploitation in proportion to encounter frequency," combined with low faunal density. One might say that the very unpredictability of the environment is in itself predictable with a response of continual residential movement.

An example of hunter-gatherers in marginal environments utilizing a forager settlement system are the Chipewyan, who prior to the introduction of modern means of transportation, moved people to the site of moose kills (Jarvenpa and Brumbach 1983:183). Another possible example is suggested by archaeological sites near Lake Baikal in Russia, which Binford (in Moore 1989) interprets as displaying a pattern of moving consumers to resources; i.e., a forager pattern. Of further interest is the implication that these groups therefore lacked transportation technology; that if they had transportation they would have moved the resources to the people (Binford in Moore 1989).

As per the above discussions, range sizes would be expected to be quite large, on the order of the 2500 km^2 suggested earlier as a maximum size. Minimum band group size would be anticipated to range from 15 to 25, with the expectation that 15 represents the prevalent group size and 25 the maximum. Population density would be correspondingly low, presumably between 0.005 and 0.01 persons per km^2. This range is seen as primarily a reflection of group size within a given range size, i.e., a group of 25 in a range of 2500 km^2 results in a population density of 0.01p/km^2, while a group of 15 in the same area has a population density of 0.006p/km^2. The Mistassini of Quebec, for example, have a population density of 0.006p/km^2, and a minimum band size of 15 to 20 in a territory of 2490 km^2 (Rogers 1969).

Since, as mentioned above, marginal environments characterized by unpredictable resources ultimately select for open and flexible social systems (Grimes et al. 1984:170; Wobst 1974:169; Butzer 1991:148), the lower end of the range of 175 to 475 individuals for mating networks is practicable. With an absence of restrictive marriage rules, and assuming bilateral relations (Helm 1969:156), under ideal conditions a maximum band size of 175 people is large enough to ensure everyone a potential mate.

7.4.d.4 Social Costs of Hunter-Gatherers in Submarginal Environments

Thus far spatial and demographic aspects of hunter-gatherer organization in submarginal environments have been considered. The consideration of social aspects is both more complicated and pivotal to an understanding of possible dynamics of submarginal ecosystems. To put it simply, submarginal systems are anticipated to push social costs above a maximum threshold level sustainable by a hunter-gatherer population. Along with Gamble (1986:322), I am concerned with "the impact that high risk environments had on the maintenance of demographic networks which had to operate at low population densities, and where these scattered populations most probably had infrequent moments of larger group aggregation."

It has been established above that several aspects of hunter-gatherer behavior can be characterized as variables with relatively narrow ranges (Table 7.2). It is proposed that ultimately what ties all these narrowly defined ranges together is social costs. All mating networks involve social costs (Gamble 1986:61) because "mate exchange requires maintenance of a dense communication network" (Wobst 1976:51). As range size increases and population density decreases, the cost of social interaction increases because the "costs of integrating information flows over a region increase sharply as the size of the communication network grows" (Moore 1981:216), and mate exchange becomes more difficult (Butzer 1988:201).

Wobst (1976:52) argues that "at low population, it is questionable whether local groups could maintain sufficiently dense communication to assure a peaceful exchange of mates over the distances required." By low, Wobst is referring to a population density of 0.005p/km^2. His contention is

Table 7.2 Quantifiable Variables of Hunter-Gatherer Adaptations

Minimum Band Size:	always >15; usually ca. 25
Mating Network Size:	always >175; often ca. 500
Range Area:	usually ca. 300 km^2; always <2500km^2
Population Density:	rarely < 0.01; usually > 0.1

that such a population density in a 475 person network requires movement over more than 300 km, a distance he considers an upper limit in terms of prohibitive costs of travel.

Although the 300 km is sometimes presumed to refer to the diameter of the mating network (cf. Gamble 1986:53), it in fact refers to the distance between the most distant minimum bands. A mating network of 475 people with a population density of 0.005p/km^2 has a diameter of 382 km; but travel between the center of any two most distant groups will cover approximately 300 km, and this distance is considered an upper limit. "Food sharing, joint ritual, and exchange — of sufficient intensity to facilitate mate exchange — are unlikely over some of the implied distances" (Wobst 1976:52). The assumption is that there is an absolute maximum distance beyond which social costs are prohibitive.

Relationships between population density, range area, mating network diameter, and distance between minimum bands have been calculated (Table 7.3). Examination of these relationships suggests a somewhat more complex limitation than simply the maximum distance beyond which socially-induced mobility costs are prohibited. Between-group distances grow at an ever increasing rate as population density declines and mating network area increases. Instead of specifying a maximum distance beyond which mobility costs are prohibitive, the pertinent variable appears to be increase in the average socially-related mobility costs in all directions. Comparison of distances between mimimum bands within the mating network shows, for example, that maintaining any level of social interaction costs more than twice as much (measured as distance traveled) in a system with a population density of .01p/km^2 than .05p/km^2; e.g., 56.4 km versus 25.2 km for a mating network of 7 minimum bands of 25

Table 7.3 Calculated Relationships Between Population Density, Mating Network Area, Minimum Band Size, and Between Band Distances for a Mating Network of 175 Persons

		7 band mating network (25 person minimum band)		9 band mating network (20 person minimum band)		12 band mating network (15 person minimum band)	
Population Density per km^2	Total Mating Network Area[a], km^2	Area[b], km^2	Distance[c] between centers in km	Area in km^2	Distance between centers in km	Area in km^2	Distance between centers in km
.05	*3500*	*500*	*25.2*	389	22.3	292	19.3
.04	4375	625	28.2	486	24.9	365	21.6
.03	5833	833	32.6	648	28.7	486	24.9
.02	8750	1250	39.9	972	35.2	729	30.5
.01	17,500	**2500**	**56.4**	1944	49.8	1458	43.1
.009	19,444	2778	59.5	2160	52.4	1620	45.4
.008	21,875	3125	63.1	**2430**	**55.6**	1823	48.2
.007	25,000	3571	67.4	2777	59.5	2083	51.5
.006	29,167	4167	72.8	3241	64.2	2430	55.6
.0058	30,172	4310	74.1	3352	65.3	**2514**	**56.6**
.005	35,000	5000	79.8	3889	70.4	2917	60.9

[a] Mating Network Area = Mating Network Population ÷ Population Density, e.g. 175 ÷ 0.05 = 3500

[b] Area Per Minimum Band = Mating Network Area ÷ Minimum Bands Per Network, e.g. 3500 ÷ 7 = 500

[c] Distance Between Centers of Minimum Bands = The Square Root of (Area Per Minimum Band ÷ π) x 2, e.g. 500 ÷ π(3.14) = 159, $\sqrt{159}$ = 12.6, 12.6 x 2 = 25.2 (see italicized values above)

persons each (Table 7.3, column 4).

Low population densities "impose costs by stretching the size of the system and distances over which interaction has to take place" (Gamble 1986:53). That is, "as population density decreases, a point will be reached at which it becomes impossible to maintain the necessary intensity of communication without impairing the probability of survival or without the social group breaking apart for lack of communication" (Wobst 1974:155). Mussi (1990:139), for example, argues that the Aurignacian failed in Italy "because contacts were not maintained between widely dispersed groups." Furthermore, Weniger (1990:190), in a study of the Upper Paleolithic of Germany, suggests the archaeological record indicates "that environmental deterioration around the LGM [last glacial maximum] forced the Gravettians to expand their resource base and exploitation range, and resulted in the greater dispersal of these groups" and the possibility that "Gravettian groups became so dispersed that the study area was abandoned altogether." It seems that the abandonment, or cultural system failure, was due to failure of social and mating communications networks.

In conclusion, submarginal environments are nonviable because of the incompatibility of meeting both economic and social needs within the constraints imposed by an extremely depauperate environment. As outlined above, the extremely low primary productivity of extremely depauperate environments, such as has been reconstructed for the upper North Saskatchewan drainage basin, results in high mobility and low population density; i.e., dispersion of the population past the point at which social relations maintaining essential mating and information networks can be maintained.

Without mating networks, mates cannot be ensured and biological (reproductive) failure follows. Collapsed networks also would result in lack of information necessary for dealing with the variable and unpredictable environment, and the breakdown of alliance systems that acted as insurance — all leading to eventual subsistence failure. Of primary significance is that although ultimately environmentally driven, the operative factor resulting in cultural failure is social. The social aspect does not act alone but is the pivotal factor among the various aspects of hunter-gatherer adaptation. Environmental conditions causing population dispersal past the point at which social relations can be viably maintained is the systemic mechanism that links environment with culture. This is a key point that will be returned to later.

7.5 A Quantitative Approach

To this point a case has been developed that will lead to the testing of the human viability (both biological and social) of the ice-free corridor. This testing, as discussed previously, is the "specific quantitative" type, as constrasted to the "general qualitative" comparison utilized earlier in the cross-cultural comparison of the world at 18,000 B.P.

7.5.a Hypothesis

The hypothesis proposed is that the ice-free corridor (as exemplified by the upper North Saskatchewan drainage basin) was capable of supporting biologically and socially viable human populations. This hypothesis is not intuitive. However, it is the often unstated assumption, i.e., "hypothesis" implied but never tested, numerous times in stories of the first American's journey into the New World; written in invisible ink on the blank page prior to the arrival of Clovis hunters on the Great Plains.

The inherent value of a positive hypothesis is that it has the potential of being falsified or invalidated, i.e.; "it is only if a consequence is invalidated that the truth of the initial proposition can be questioned; only a negative demonstration counts" (Courbin 1988:44). Invalidation of a hypothesis is more powerful than validation because "to be validated, a proposition has to be confirmed many times" (Courbin 1988:44).

7.5.b Test Implications

If the ice-free corridor was a viable human environment, then,

1) there should be archaeological evidence of human occupation within the corridor;

2) there should be vertebrate evidence indicating potential faunal biomass within the corridor;

3) there should be paleolimnological evidence of productive lakes within the corridor, and most critically;

4) there should be paleoenvironmental evidence indicating primary production values above a level capable of supporting 175 people within an area small enough to ensure viable mating networks.

Implications 1 to 3 above have commonly been utilized in qualitative evaluations of the corridor. However these implications are difficult to test for two reasons. First, there is a lack of evidence for the period of interest. As mentioned earlier, absence of evidence does not equal evidence of absence. Nevertheless, in the absence of evidence, these implications cannot be tested. Additionally, their contribution as negative evidence can play only a circumstantial role; that is, the lack of archaeological sites in the corridor prior to 11,000 years ago suggests the nonviability of the environment, but proves nothing. The same holds true for the lack of paleontological remains between 22,000 and 12,000 years ago (Burns 1989), or productive lakes prior to 11,000 years ago. As White and O'Connell

(1982:42) state, "negative evidence is, of course, about the weakest there is."

Second, even if archaeological, paleontological, and other data were available, it could not necessarily be evaluated in a quantitative manner. For example, a paleontological site could indicate presence of game, but not the potential abundance of whatever species it contained. Even an archaeological site would not unequivocally indicate viability of the corridor. As just stated above, in order to "be validated, a proposition has to be confirmed many times" (Courbin 1988:44). Several archaeological sites and demonstrated cultural dynamics might be support for environmental viability. A single site could, conversely, be evidence of nonviability.

Since many demographic investigations focus on the "probability of survival of small isolated populations" (MacCluer and Dyke 1976:1), often the implication that many small populations fail to survive is forgotten. A computer simulation study evaluating the growth of small populations in reference to the initial colonization of Australia concluded that founding groups of 6 to 14 individuals had minimum probabilities of extinction ranging from 15% to 77%, depending on group size, spouse age, and other variables (McArthur 1976:54). This study was done without any consideration of social aspects, mate availability, or any variables outside of the typical demographic measures of fertility, and lifespan.

In a discussion concerning the number of migrations into the New World, Meltzer (1989:481) argues that although many researchers believe there were a limited number of migrations, we should resist assuming that there "was a low number of arrow-like purposeful migrations, each a discrete episode involving a small coherent founding population." That is, "there could have been hundreds, perhaps thousands of separate arrivals of small populations from Asia" (Meltzer 1989:274).

Meltzer (1989:482) further notes

> that the possibility that there was one or more early *successful* migrations logically implies the possibility of early *unsuccessful* migrations (Haynes 1967:280). Unsuccessful or *failed* migrations, in strict evolutionary terms, would be those that penetrated the continent but subsequently disappeared without issue or without detectable mixture (genetic) with indigenous groups . . . [These] failed migrations would be invisible among modern populations.

The point is that we shouldn't forget that "extreme environmental conditions increase the risk of failure" (Low 1990:229), nor be surprised if some colonization attempts (not to imply they were intentional) were failures due to nonviability of the environment.

> Extinction is the natural by-product of migration by founder populations that failed to respond adaptively to changing environmental conditions or were unable to reach sufficiently large size for viable reproduction (MacArthur 1972:89; Simpson 1953:293-303). Such is the regular fate of peripheral isolate populations under adverse conditions (Mayr 1970:305) (Meltzer 1989:482).

To return to the issue of the test implications, as mentioned above, the first three implications cannot be tested because of a lack of data. However, implication 4 can be tested. First, there is a data base to work from; i.e, pollen records from lake basins within the corridor area. Second, pollen is an extremely abundant fossil, allowing for the application of statistical treatments and quantitative evaluation of environmental parameters.

7.5.c Assumptions

Although many of the following assumptions can be deduced from the preceding discussion and analysis, it is useful to state them explicitly.

1) Variations in the environmentally determined distributions of biotic and abiotic resources act to constrain human behavior.

2) General principles of human behavior derived by analogy from modern hunter-gatherers can be expected to be applicable to human behavior during late Upper Paleolithic times; that is, such analogy is used "as a heuristic or explanatory device to outline possible contours of past behavior but in no way to delimit it" (Soffer 1985:15).

3) Human groups living in the corridor area as reconstructed for this study are assumed to have no transportation aids that would work to decrease mobility costs. As emphasized earlier, the major determining factor in the nature of the corridor's environment is extreme aridity, not simply low temperatures. Because of this aridity, the arctic adaptations often assumed to be generally applicable in high latitude environments, e.g. sleds and snow shoes, would be inapplicable in the corridor.

The corridor as reconstructed here presents a unique set of extremely cold, dry, windy conditions with sparse precipitation (i.e. minimal snow), yet no loess deposition due to the unique drainage patterns and ice configurations of the region. This is an environment with no known modern analogues, either environmental or ethnographic.

4) The maximum range utilized by hunter-gathers having no transportation aids is approximately 2500 km^2 because "if resources are so dispersed that not enough food can be obtained in an area of this size . . . it is likely that groups would have to expend more energy acquiring food than they could derive from consuming it" (Hayden 1981a:382); i.e., they die.

5) The hunter-gatherer social landscape consisted of maximum social bands (mating networks) divided into minimum subsistence bands (Wobst 1974; Dennel 1983), averaging 175 and 15 individuals, respectively.

6) Minimum population density is assumed to be 0.0058 persons per km^2, based on the above range size of 2500 km^2 and minimum band of 15 as

per earlier discussions.

7) Basic human physiological requirements are assumed to have remained "unchanged despite several thousand years of microevolution of some physical characteristics" (Henneberg and Ostoja-Zagorski 1984:48).

8) The diet of potential inhabitants of the study areas during the time periods in question is assumed to have consisted primarily of meat. It has been demonstrated that as temperature and primary productivity of the environment decrease, percentage of meat in the diet increases (Kelly 1983; Belovsky 1987). An assumption of a "meat-centric" diet is particularly valid for periglacial regions where plants are sparse and important only indirectly through the food chain (Gordon 1975:31; Soffer 1985:239). Furthermore, it is likely marine resources were not of primary importance until near the end of the Pleistocene (Hayden et al. 1987:289).

9) Hunter-gatherer population densities are strongly related to food availability. It has been demonstrated that nutritional intake limits population growth, as population is a function of nutrition and nutrition depends on availability of food; i.e., there is a "minimum harvestable primary productivity that hunter-gatherers require to maintain a viable population (a positive population size over time)" (Belovsky 1988:345). Although Reidhead (1979:558) warns that energy-based models can overestimate carrying capacity, the constraints of the resolving power of palynology limit the ability to deal with food as a limiting factor on a finer level than calories or energy.

10) Food availability can be estimated from environmental maximum harvestable primary production and the level of exploitation by humans (Belovsky 1988:345).

11) Since total pollen influx values can distinguish between

vegetation formations (Birks and Birks 1980:225), comparison with modern physiognomic vegetation formations allows estimation of primary productivity values for paleovegetational assemblages based on primary production of comparable modern vegetation formations.

7.5.d Modeling the Ecosystem

Wilson (1990:77) has discussed the need to reconstruct past landscapes in order to understand their cultural occupants with the ultimate goal of integrating paleoenvironmental data with landscape characteristics to provide a context for the evaluation of human cultural systems. Accordingly, the first step in evaluation of the viability of the ice-free corridor as exemplified by the upper North Saskatchewan drainage basin is reconstruction of the landscape of the region.

Crumley and Marquardt (1990) have stressed that because they are dynamic, varying on spatial and temporal scales, regions are inadequately conceptualized if temporal and spatial relations are unspecified. Paleogeographic maps of the upper North Saskatchewan drainage basin (Figures 7.5 to 7.9) depicting landscape parameters at several different time periods allow for an appreciation of spatial and temporal variability at the mesoscale level, i.e., the level of analysis "at which details of past lives merge into process" (Dincauze 1987:265). While small- and large-scale variables are usually active and relatively easy to identify, at mesoscales (i.e., regional), "many more and less easily defined and studied variables must be accounted for" (Dincauze 1987:265).

"Regional-scale paleogeographic reconstructions are typically speculative and generalized" (Dincauze 1987:268), because maps (of any kind), in reality, are not reality; they are models. And models "simplify reality, there is no alternative" (Gamble 1986:30). All models are

Legend for Figures 7.5b to 7.9

▤	West side of basin, active and/or permanent ice; east side of basin, Stage I (youth) stagnant ice
◌	Stage II (mature) stagnant ice
⁘	Stage II/Stage III (old age) stagnant ice mosaic
▒	Proglacial Lakes
∼	Modern River System

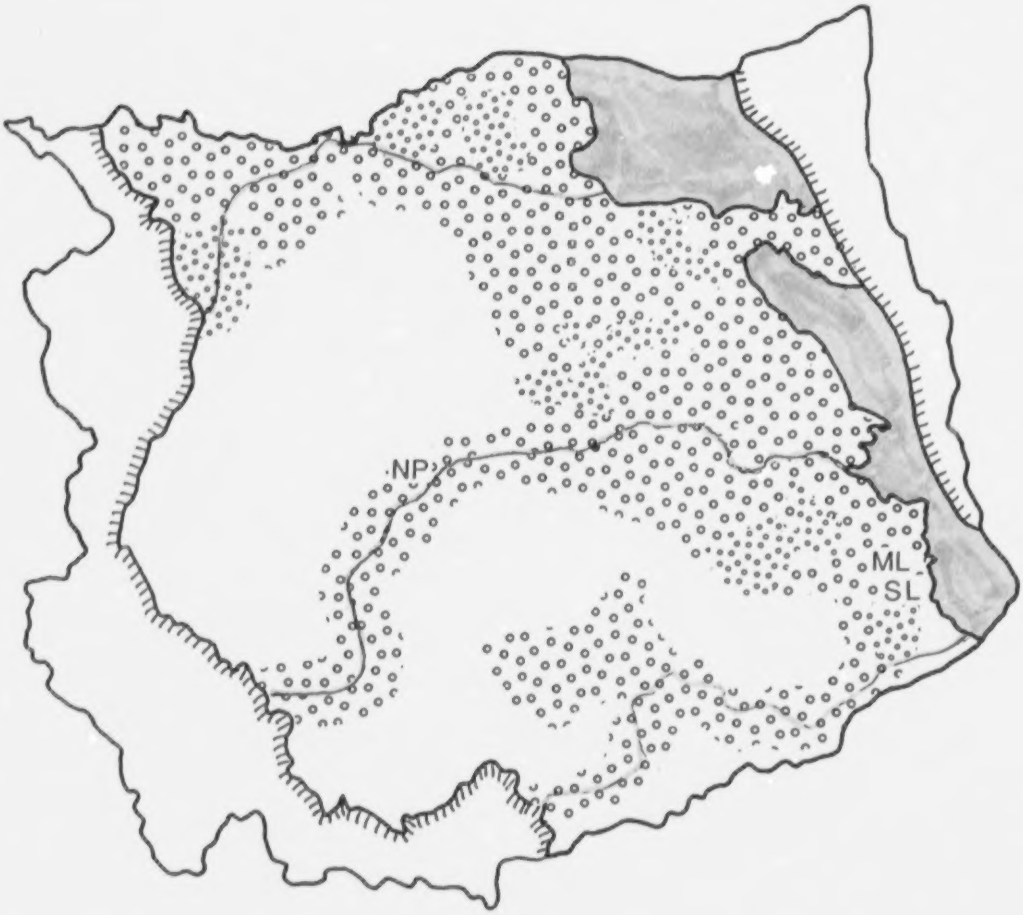


Figure 7.5b Paleogeographic Map of the upper North Saskatchewan Drainage Basin ca. 18,000 yr B.P.

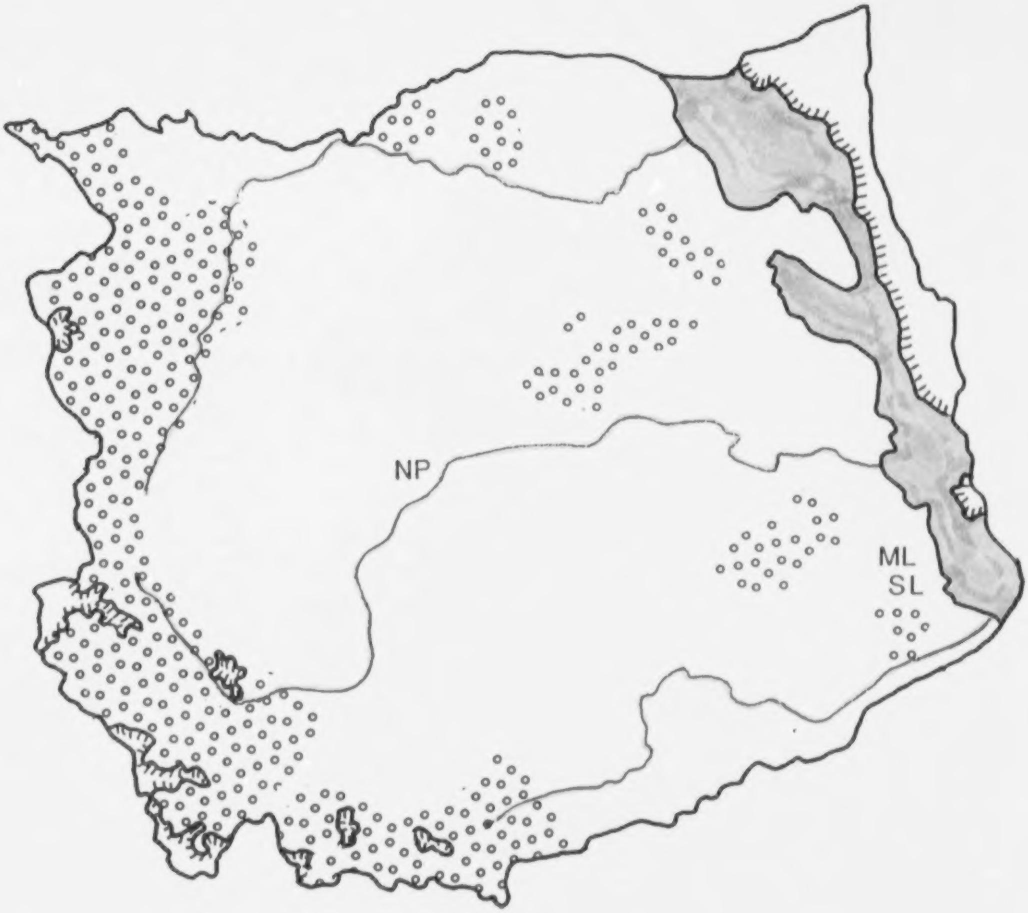


Figure 7.6 Paleogeographic Map of the upper North Saskatchewan Drainage Basin ca.16,000 yr B.P.

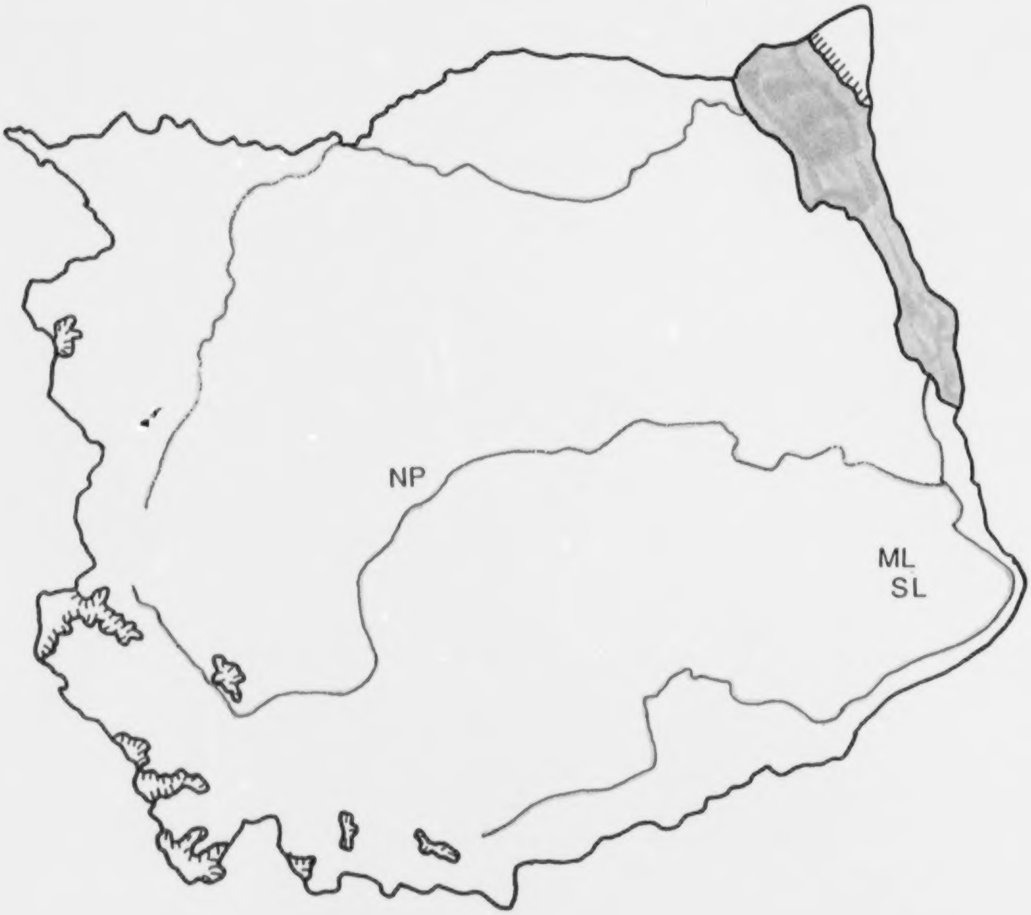


Figure 7.7 Paleogeographic Map of the upper North Saskatchewan Drainage Basin ca. 14,000 yr B.P.

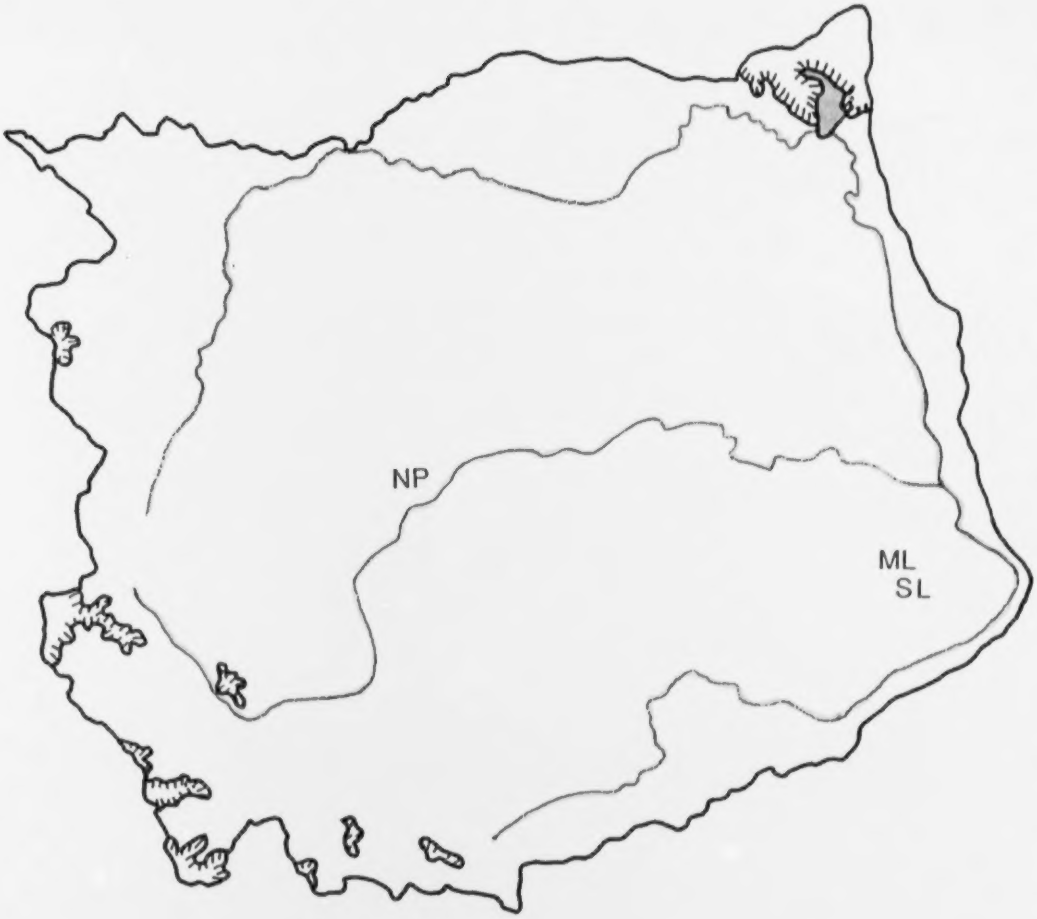


Figure 7.8 Paleogeographic Map of the upper North Saskatchewan Drainage Basin ca. 13,000 yr B.P.

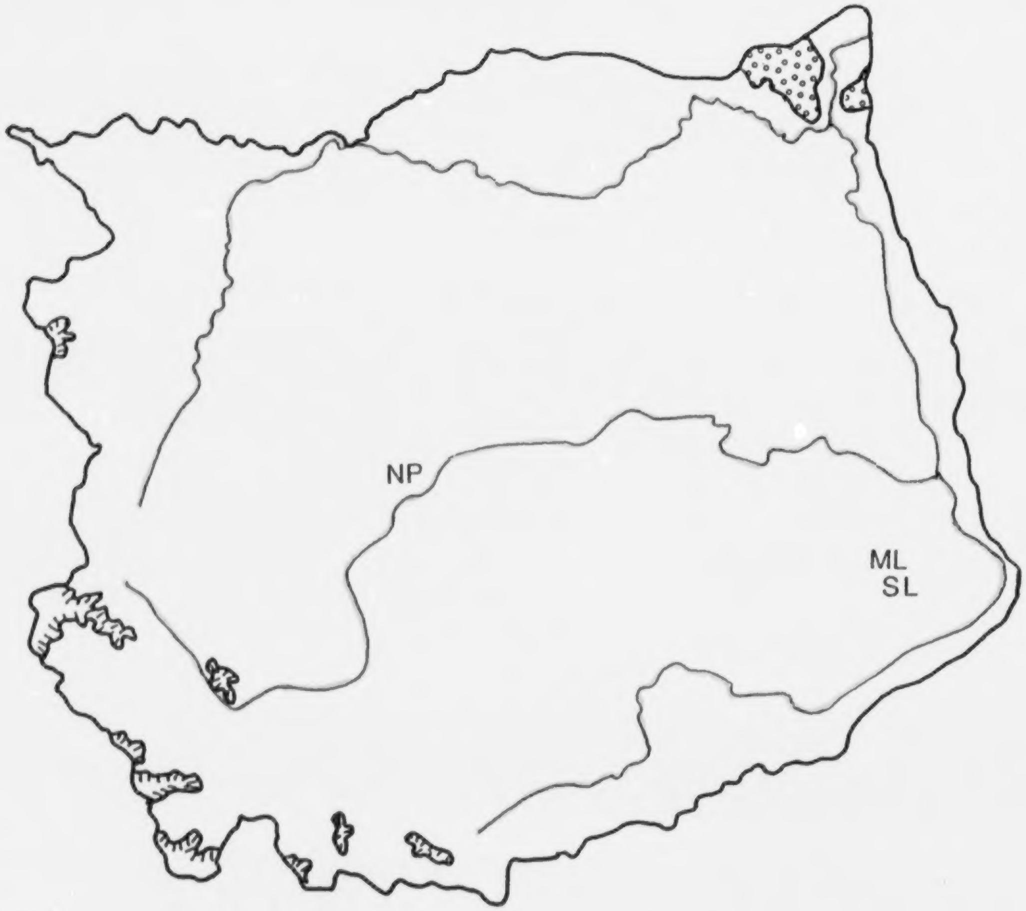


Figure 7.9 Paleogeographic Map of the upper North Saskatchewan Drainage Basin ca. 12,000 yr B.P.

simplifications of the ideas or data they represent, omitting "aspects which are either unknown or not understood" (Dove 1984:12). Models artificially simplify multivariate realities so that only essential components applicable to the problem are included (Dincauze 1981:73; Dove 1984:71). Thus "construction of a model invariably leads to idealizations and approximate results" (Henneberg and Ostoja-Zagorski 1984:42).

Two requirements of models are that they 1) cannot lose sight of the data base, and 2) must be appropriately scaled to the data (Snow 1981:118). Thus the construction of a mesoscale or regional model requires compilation of detailed local and regional studies, accompanied by a critical evaluation of both positive and negative evidence (Dincauze 1987:267). This analysis has been done for the upper North Saskatchewan drainage basin for both abiotic and biotic details. All available data have been drawn together to form a broad general picture, with specific details where possible.

Geological and geographical data relating to ice boundaries covers only sections of the region and at varying levels of analysis, but presented no major conflicts in interpretation. Evidence from larger-scale studies was used occasionally to supplement gaps in the regional data base. Glacial lake boundaries are based on surficial geology sediment types in conjunction with reconstructed ice borders, slope and elevation levels, and paleo-outlet channels. Stagnant ice designations outside of the areas mapped by Kvill (1985) and Boydell (1978) are based on former ice boundaries and rates of stagnation as per the discussion in Chapter 6.

Vegetation, though not shown on the maps, is assumed to be distributed as follows: for maps at 18,000, 16,000, 14,000, and 13,000 years ago, vegetation as reconstructed for Mitchell and Strubel lakes at those time periods is assumed to characterize all land under 1829 m (6000 ft); for the map at 12,000 years ago vegetation as reconstructed for Mitchell and Strubel lakes is assumed to characterize land below 1219 m (4000 ft), while vegetation as reconstructed for Nordegg Pond is assumed to characterize land between 1219 m and 1829 m. Admittedly, such assumptions are not entirely realistic.

As discussed earlier, models cannot simultaneously be realistic, precise, and general; but can only maximize two of these aspects. In addition, quantitative analysis was characterized as essentially general and precise in nature, i.e., not realistic. It is in this sense that my assumptions regarding vegetation are not realistic — that is, realistic as in accurately depicting the complexity of the real world, not realistic as in reasonable — as they are in fact reasonable.

Realistic is defined as "depicting things as they really are, without idealizing" (Davies 1973:587). Yet most models, especially ecological and paleoenvironmental models, "reduce reality to generalized form" (Whynne-Hammond 1985:21). This is true to a certain extent of even the abiotic aspects of the paleogeographic reconstruction owing to the amount of data available, but it is inherent in the very nature of paleoenvironmental analysis. Due to the regional scale of palynological data, paleoenvironmental reconstructions are not precise enough to resolve fine scale environmental variability; i.e., we can reconstruct composition, but not the structure of the environment (Dincauze 1981:73; Jochim 1990;76; Guthrie 1990a:76).

Butzer (1990:94) admits that "simulation or even quantification of entire ecosystems may be impossible," while Dincauze (1987:292) concludes "here is the ultimate paradox of environmental reconstruction; you cannot really do it." Lest these pronouncements sound overly pessimistic, it should be noted they are referring to realistic; i.e., non-idealized reconstruction. The simple fact is that palynology cannot be used to reconstruct the spatial patterning and structure of vegetation at the scale of "microvegetation' zones or to quantify the resources of such zones in a meaningful manner" (King and Graham 1981:134).

In reality, "we can identify only coarse-grained, major biotic zones and must depend upon analogy with modern habitats to estimate the spatial distribution of the plant . . . components" (Jochim 1990:84). For example, "plant distributions can frequently be shown to correspond to basic environmental factors of climate or soils or topography" (King and Graham 1981:133); e.g., moisture availability, soil texture, aspect, and elevation (Walter 1979:115). This provides criteria for the definition of, for example, elevation dependent vegetation zones (cf. Zutter 1987).

It is on such a basis that I delineated the paleovegetation communities described above. Admittedly not realistic in terms of environmental structure, as vegetation types do not spread themselves in even distributions across the landscape, it is of necessity "a conceptual compromise" (Dincauze 1981:73). King and Graham (1981:129) note that "general appearance, or physiognomy, is a useful method of delineating communities." It is also, at times, along with identification of species composition, the most that can be done without overextending the vegetational reconstruction beyond the limits of the data base.

Utilizing the 1219 m elevation line as the border between the two major vegetational communities described for Mitchell and Strubel Lake and Nordegg Pond pollen assemblages does not of course imply an abrupt change in vegetational composition. As Barbour et al. (1980:198) explain, "many of the boundary lines drawn on vegetation maps do not exist in nature. One community or vegetation type will typically change gradually into an adjacent one through a broad ecotone. The line on the map may represent the midpoint of that ecotone." Thus the 1219 m elevation line indicates such an ecotonal midpoint.

7.5.e Quantifying the Full- and Late-Glacial North Saskatchewan Valley Ecosystem Model

7.5.e.1 Nutritional Needs of the Population

Estimates of mean daily requirements generally range from 2200 to 3000 calories for an average adult; i.e., male and female needs averaged (Gamble 1987:91). Values of approximately 2200 calories a day are cited as typical for temperate zones (Belovsky 1988:48: Winterhalder et al. 1988:Table 4). Values of 3000 calories are felt to be required for colder areas because of increased energy requirements (Hassan (1981:18). It is not specified how cold an environment must be to require 3000 calories a day. However, Gamble (1986:113), cites 2750 calories/day as the mean requirement for adults in environments with an average annual mean temperature of 5°C. This is a commonly cited value that appears to be an average of separate "typical" estimates of 3200 calories/day for men and 2300 calories/day for women (e.g., Snow 1981:124). All of the above values include basic metabolic requirements plus reproduction requirements; i.e., "a sufficient nutritional intake to ensure that an adult living to senescence would leave one surviving offspring" (Belovsky 1988:336).

The 3000 calories/day upper range is considered the absolute minimum requirement for humans in the study area because,

1) the modern temperature in the region is well below 5°C, ranging from 3°C at Rocky Mountain House (Alberta Environment 1987:155) in the

eastern lower elevations to 0.7°C at Nordegg (Alberta Environment 1987:133) in the central higher elevations, and was clearly colder for much of the period in question; and

2) "persons whose diets are high in protein experience higher metabolic rates than those whose diets are composed largely of carbohydrate" (Speth and Spielman 1983:6). Furthermore, it has been noted that among the Inuit strenuous hunting can require as much as an additional 600 to 2000 calories/day (Moran 1982:119; Speth and Spielman 1983:12).

Caloric needs were calculated for a minimum band of 15 (Table 7.4) based on Henneberg and Ostoja-Zagorski's (1984:Table 1) estimates of age structure and ratios of adult nutritional needs of Upper Paleolithic populations, and the above assumption of 3000 calories/day as a minimum adult requirement. It is estimated that such a band would require a minimum of 38,940 calories a day. As Belovsky (1988:334-335) indicates,

> the important aspect of nutritional status is not the amount ingested but the amount ingested above the nutritional requirements . . . If this value is positive, a surplus is indicated and it can be used for reproduction, while if this value is negative, a shortfall is indicated and it must be eliminated by mortality.

7.5.e.2 Environmental Variables

Given that "environmental production sets upper limits to the human food base" (Belovsky 1988:340), the goal here is to establish whether upper limits of the potential human food base, as determined by environmental production, are in fact below the minimum harvestable primary productivity that the population requires to maintain a viable population. The minimum harvestable primary production is a function of the maximum environmental primary production. Total pollen

Table 7.4 Age Structure and Caloric Needs of Upper Paleolithic Bands

Age	Required kcal	15 person band	20 person band	25 person band
0 - 1	840	1	1	1
1 - 3	1410	1	1	2
4 - 6	1860	1	1	2
7 - 9	2280	1	2	2
10 - 12	2730	2	2	2
13 - 15	3120	1	2	2
16 - 19	3270	1	2	2
20 - 49	3000	6	8	10
50 +	2700	1	1	2
	TOTAL kcal per band =	38,940	53,610	65,580

Based on Henneberg and Ostoja-Zagorski (1984) influx values averaged from samples bracketing the years in question were compared with modern pollen influx and primary production values from comparable arctic and desert vegetation types in order to estimate maximum primary production values for the study area (Table 7.5).

Various proportions of primary production cannot be consumed "because of inedible structural components. Therefore, the primary production . . . must be reduced to reflect the portion that is usable: low fiber content (leaves, fruit, new twigs, etc.)" (Belovsky 1987:51). Harvestable primary production is calculated from the estimated primary production using Belovsky's (1987:51) regression equation $y = 16.59x^{-.59}$ where x equals the maximum primary production of the environment, and y equals the percent of primary production potentially consumable by humans or animals.

Once harvestable primary production is determined, prey biomass can be estimated, as "ecological studies demonstrate that the maximum environmental biomass of . . . prey animals [> 10 kg] is a function of plant productivity" (Belovsky 1988:339). Prey biomass is calculated from harvestable primary production using Belovsky's (1988:339) regression equation $y = .00033x^{1.49}$, where x equals harvestable primary production in grams per m^2 and y equals prey biomass in grams per m^2.

7.5.f Testing Ecosystem Viability

7.5.f.1 Optimum Yield Method

The approach utilized for evaluating population nutritional viability may be called the optimum yield method. This method approximates Hassan's (1981) model for estimating hunter-gatherer population densities. The maximum harvestable primary production of an environment as defined above is what Hassan would refer to as the "maximum" carrying

Table 7.5 Pollen Influx and Estimated Primary Productivity of Reconstructed Vegetation Associations

Time Period	Age yr B.P.	Vegetation Association	Average Pollen Influx, g cm^{-2} yr^{-1}	Estimated Primary Production[a], g m^{-2} yr^{-1}
Full-glacial	18,000	Semiarid *Artemisia* steppe	63	20
Late-glacial	16,000	*Artemisia-Betula* shrubland	247	70
"	14,000	"	303	85
"	13,000	"	817	225
"	12,000	*Artemisia-Betula* shrubland / *Artemisia-Populus* steppe parkland	1030 / 600[b]	400 / 165 (Total = 270)
Post-glacial	11,000	*Picea* woodland/ *Artemisia-Populus* steppe parkland	1332 / 600[b]	500 / 230 (Total = 351)
"	10,000	*Picea* woodland/ *Betula* shrubland	2414 / 6000[b]	935 / 2000 (Total = 1524)

[a] Primary production values based on pollen influx values (Birks 1973:147; Birks 77:2378; Birks and Birks 1980:225; Davis and Jacobson 1985:349; Funder and Abrahamsen 1988:196; Ritchie and Lichti-Federovich 1967:261), and primary productivity values (Barbour et al. 1980:248,501; Bliss 1973:369; Muc 1972:126; Henry 1990:125; Rickard and Vaughn 1988) of modern vegetation.

[b] Influx values from Goldeye Lake values after recalibrating dates using pollen curves at Nordegg Pond and recalculating influx (because shorter time span). Goldeye Lake values used instead of Nordegg Pond values because they are more likely representative of regional vegetation.

capacity of an environment. Traditional estimates of human carrying capacity overestimated human population because they simply divided the maximum level of environment productivity by average human needs to arrive at an estimate of population density (cf. Casteel 1972). This approach failed to take into consideration the fluctuations in abundance and density of critical resources (Hassan 1981:29; Winterhalder et al. 1988:290), or the impact of humans on the resource base, i.e., "all the food in the environment cannot be consumed without decreasing its recovery rate or decreasing the ability of the consumer to harvest it in the available feeding time." (Belovsky 1988:330). If such considerations are taken into effect, a level Hassan calls the "critical" carrying capacity can be calculated and used to estimate the maximum population that could be supported without critically affecting the resource base. Critical carrying capacity is not, however, a truly viable population level since as Hassan (1981:167) points out, living at the critical level could be quite disruptive to populations because they would be prone to severe environmentally driven fluctuations. He speculates that "populations would cushion themselves against severe shortages or stochastic population fluctuation by existing below the critical carrying capacity at a level that we may refer to as the "optimum" carrying capacity" (Hassan 1981:167). Such an optimum level also considers more recent considerations regarding dynamic interaction between the human population and the biomass of exploitable resources (Winterhalder et al. 1988:321).

> Anthropological studies offer few generalities more often repeated and analytically suggestive than the observation that hunter-gatherers 'live below the carrying capacity of their environment.' But to phrase the point this way surely is to misconstrue it . . . Forager and prey biomass are interdependent (Winterhalder et al. 1988:322).

Thus the concept of humans living "below" carrying capacity only makes sense if one is referring to the maximum carrying capacity as defined by Hassan (i.e., maximum environmental primary production), which is not equivalent to the actual human carrying capacity. If the phrase carrying capacity is to be used at all it should be understood that hunter-gatherer populations do not live below carrying capacity because the carrying capacity is the actual level at which the population does in fact live. The environment cannot "carry" any more people at a given technological level without sustaining possible negative consequences. When the phrase "carrying capacity" is used in reference to maximum human population levels an environment can support, it should be referring to the optimum carrying capacity as defined by Hassan and not higher levels that in fact simply refer to maximum environmental biomass levels.

The yield available to a population inhabiting an annual range of 2500km^2 at an optimum carrying capacity as defined above can be calculated with the formula

$$(B) \times X \times E \times W \times M\ (3.75 \text{ x } 10^6) \div 365 = \text{calories/day}$$

where the variables are defined as follows:

B, refers to maximum environmental biomass of prey animals measured in kg/km^2 as defined and calculated above using Belovsky's (1988) equations for calculating prey biomass,

X, refers to extraction rate measured as a percent of total prey biomass. The "extraction rate that would not damage biotic potential or the ecological network of ungulates is between 3 and 10%, with an average of 5%" (Hassan 1981:31) of total prey biomass. That is, it is estimated that over the long term, an average of 5% extraction of total prey biomass will not be disruptive.

M, refers to what Hassan (1981:31) calls the "safety margin" that acts "in order to avoid exposing the population to food shortage as a result of seasonal and short-term violent fluctuations." That is, the extraction rate must be decreased below the long term average sustainable level in order to deal with potential seasonal or interannual fluctuations in the resource base. The safety margin is estimated as between 20% and 60% (with an average of 40%) of the optimum yield extracted (Hassan 1981:31).

The concept of safety margin has traditionally been viewed as a conscious effort by hunter-gatherers not to overexploit the environment. However, it is now being questioned by some (cf. Keegan and Diamond 1987) whether hunter-gatherers did consciously limit themselves in order to limit stress on the environment. Utilization of the 40% safety margin need not, however, imply cognitive intent. In view of the fact that the value "works" when applied to known hunter-gatherer groups, it may be estimating some noncultural way hunter-gatherers are limited to accessing 40% of the available resources. Kelly (1983:296) notes that "while hunter-gatherers dependent on fauna may use large tracts of land annually, they do not necessarily cover this land thoroughly." Perhaps the 40% level measures an accessibility factor; i.e., resources can only be obtained from areas actually covered by hunter-gatherers within their range.

E, refers to the percentage of individual prey weight that is edible. This is usually estimated as 60% (Henneberg and Ostoja-Zagorski 1984:60: Soffer 1985:205), although Hassan (1981:31) puts it at 50%.

W, refers to the percentage of prey weight lost through waste and spoilage, estimated by Hassan (1981:31) at 10%.

The waste and spoilage factor and edibility factors combined estimate a total of 54% edible meat (i.e., 0.60 × 0.90 = 0.54). By comparison, Belovsky (1988:340) combines the waste and spoilage factor (including loss due to consumption by dogs) and the edibility factor into a variable equivalent to 15%. Using the values of 60% and 10% in these calculations might in fact overestimate meat availability.

3.75×10^6, converts kg/km^2 of extractable prey biomass to calories/2500km^2 in order to estimate total available biomass in terms of calories. Estimates for calories derived from 1 kg of meat vary widely, ranging from 483 to 2700 calories with an average of approximately 1500 calories. Even though most of the variation in calories is due to fat content, and game meat tends to be relatively low in fat (Belovsky, personal communication), the average value of 1500 is used here in order not to underestimate the calories provided.

365, converts annual calories available to daily calories available, which can then be compared to daily calorie requirements of the population.

One variable not included in the calculation is that of selectivity, which (Hassan 1981:31) estimates at 70% of total species available for most hunter-gatherers but at 100% for Eskimos. Hayden (1981a:400) also notes that hunter-gatherers in cold and arid areas tend to eat all types of animals and all animal parts. Essentially hunter-gatherers in such areas cannot afford to be selective. An assumption of 100% selectivity negates the need for inclusion of this variable.

There is a certain amount of imprecision involved in assigning numbers to environmental variables. Henneberg and Ostoja-Zagorski's (1984:42) caution that "the numerical data we use, despite their seemingly exact character, should be treated as quantitative approximations of real situations," also applies to this study. This consideration should, however, only minimally impact on basic points in the arguments presented here. Should additional and/or better data become available, whether for pollen influx values in the study area, primary productivity on representative vegetation types, sustainable extraction rates, and/or daily calorie estimates of hunter-gatherers, the region can always be reevaluated using the same assumptions and relationships presented here.

7.5.f.2 Results and Analysis

The above calculations were done for 18,000, 16,000, 14,000, 13,000, 12,000, 11,000, and 10,000 years ago (Table 7.6). Column 6 (italics) indicates maximum calories/day available for a hunter-gatherer band with a range of 2500 km^2, since as discussed earlier, this is the maximum viable range size for hunter-gatherers. It should be noted that this is, of course, an averaged daily rate, not taking lean seasons into consideration. However, it is clear that even if resources could be averaged throughout the year, the environment at 18,000, 16,000, and 14,000 years ago provides inadequate biomass to sustain a band of 15 hunter-gatherers, providing only 8% to 70% of the minimum daily requirement of 38,940 calories (Table 7.4). Thus, if the environment cannot support a population when resources are averaged, it clearly cannot support it when resources are at minimum levels.

The calculated value of 65,887 calories/day provided by the environment 13,000 years ago at first glance appears to indicate potential human viability. However, it must be realized that to this point only nutritional requirements have been evaluated. As discussed earlier, social viability also needs to be considered. Social costs, measured in terms of mobility can be calculated using distance as the variable measured as per earlier discussions. To evaluate social viability at 13,000 years ago we need

Table 7.6 Optimum Yield Calculation Data and Results

	1	**2**	**3**	**4**	**5**	***6***	**7**
Time Period	Study Area[a] in km^2	Estimated Primary Prod.[b] in g/m^2	Harvest-able P.P.[c], g/m^2	Prey Biomass in kg/km^2	Total kg in tons per 2500km^2	*cal/day available in 2500km^2*	cal/day available in 1308km^2
18,000	10,665	20	20	28.6	305	*3173*	1660
16,000	11,306	70	70	185.2	2094	*20,550*	10,752
14,000	12,478	85	85	247.4	3087	*27,451*	14,362
13,000	13,319	225	153	593.8	7909	*65,887*	**34,472**
12,000	13,355	270	230	1090	14,557	*120,945*	63,278
11,000	13,355	351	280	1461	19,512	*162,111*	84,816
10,000	13,355	1524	335	1909	25,495	*211,821*	110,825

[a] Area of region equals land available outside of ice and glacial lake borders (Figures 7.6 - 7.10) and below 6000 feet (1828m) as calculated by ARC/INFO geographic information system.

[b] Values for 12,000, 11,000, and 10,000 years are averaged prorated values based on percentage of land above and below 4000 feet (1219m) as calculated by ARC/INFO and applied to values in column 4 of Table 7.4.

[c] Values calculated for nonherbaceaous vegetation units only.

to return to the concept of average distance between minimum bands within a mating network.

The average distance between minimum bands characterized by range sizes of ca. 2500 km^2 remains the same (Table 7.3, bold type); i.e., approximately 56 km, when group size and thus population density change. This relationship is obvious, as the area per band is not changing. One might assume, therefore, that mobility costs are equivalent as long as range size remains constant. While this assumption is true for subsistence related mobility costs, it is not the case for socially related mobility costs, as when the number of individuals per minimum band decreases, the number of minimum bands per 175 person mating network increases. That is, there is an inverse relationship between the size of the minimum band and the number of minimum bands within a population of constant size. For example, a 175 person mating network,

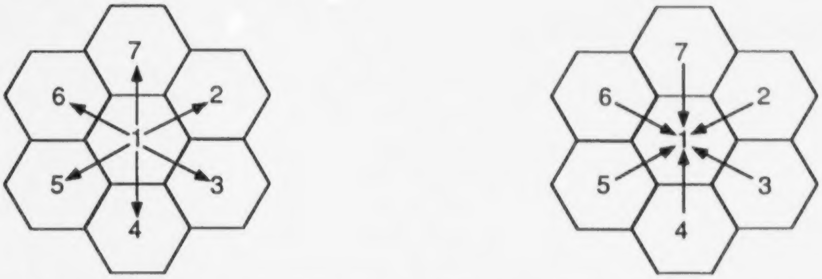
1) with 25 persons per minimum band, would have 7 bands,
2) with 20 persons per minimum band, would have 9 bands, and
3) with 15 persons per minimum band, would have 12 bands.

Because mating network limitations require access to a minimum of 175 members, we must consider the cost of social communication to all members, in all bands, not just the ideal seven. As the number of bands rises, even as average distance stays the same, the total distance necessary for minimum social contact increases. The minimum social cost of maintaining mating networks can be estimated as the total distance traveled to allow one round trip to each of the other bands within the network. Although such travel was not necessarily the case, it is a convenient way of estimating the relative potential mobility costs of minimum social contact.

The method for calculating costs can be illustrated with the ideal seven band hexagonal packing of 25 member minimum bands (Fig. 7.10). The distance traveled in one round trip to each of the other bands in the network is twice the distance between centers of neighboring hexagons. The distance between centers is equal to two radii or one diameter of a minimum band's hexagonal range. A single visit and return trip requires traveling a total distance of two diameters. Thus for band #1, the social cost is 6 round trips for a total of 12 diameters. Bands #2 - #7 will have greater social costs than band #1 because of their noncentral location. Band #2, for example, has a social cost of 6 diameters in total for its closest neighbors (bands #1, #3, and #7) plus 2 times 6 diameters for distant neighbors (bands #4, #5, and #6) for a total of 18 diameters. Bands #3 through #7 would similarly have social costs of 18 diameters each. The social cost for the entire mating network of 7 bands is calculated as 120 diameters, or 12 + (18 x 6). Multiplying the total number of diameters by the diameter distance of 56 km (the average distance between minimum bands within a range of 2500 km^2) results in a total social cost for the mating network of 6720 km. Dividing this number by 7 (number of minimum bands) results in an average social cost per minimum band of 960 km. Average social costs similarly calculated for optimally packed mating networks of 9 and 12 bands each (Fig. 7.11a,b) are 1518 km and 2380 km respectively (Table 7.7). Having previously established that a minimum band of 15 in an area of 2500 km^2, associated with a population density of .0058 persons per km^2, is the minimum viable combination of demographic variables because of mobility cost limitations, it can be assumed that theaverage social costs associated with it, i.e., 2380 km per minimum band, are the maximum sustainable by a mating network.

Figure 7.10 Calculating Social Costs as Distance Traveled in a 175 Person Mating Network with 7 Minimum Bands of 25 persons each (.01p/km^2)

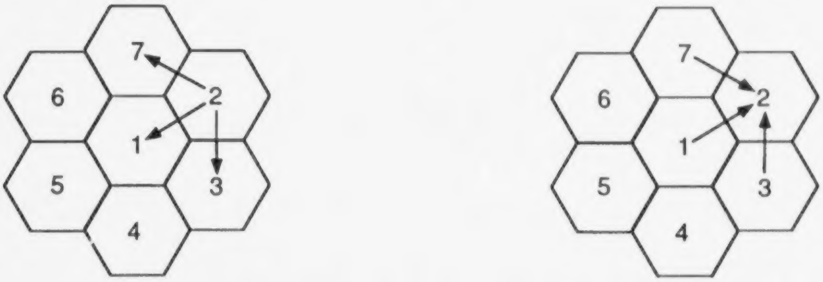
a) Band #1



6 one-way trips of one diameter each = 6d   6 return trips of one diameter each = 6d

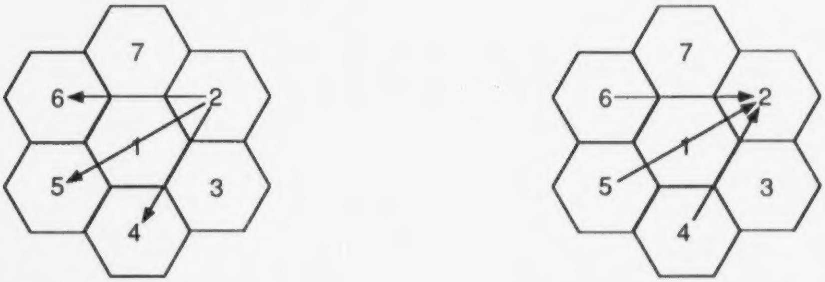
6d + 6d = 12 diameters social cost for central band

b) Band #2



3 one-way trips of one diameter each for closest neighbors = 3d

3 return trips of one diameter each for closest neighbors = 3d

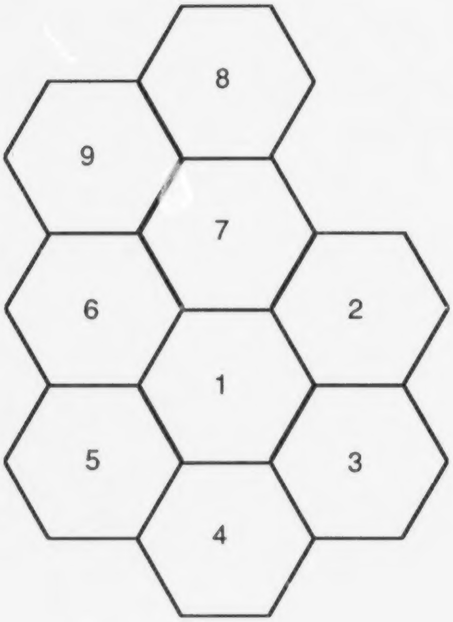


3 one-way trips of two diameters each for distant neighbors = 6d

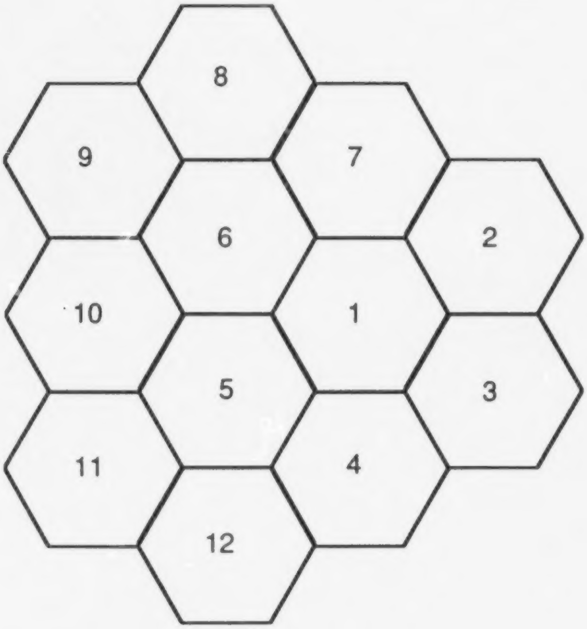
3 return trips of two diameters each for distant neighbors = 6d

3d + 3d + 6d + 6d = 18 diameters social cost for Band #2 (or #3, 4, 5, 6, or 7)
Total social cost for network = 12 + (6 x 18) = 120 diameters

Figure 7.11 Optimal Band Packing in Mating Network of 175 Persons at Varying Population Densities



a) 9 bands of 20 persons each
(.008p/km^2)


8
9
7
6
2
10
1
5
3
11
4
12

b) 12 bands of 15 persons each
(.0058p/km^2)

Table 7.7 Relationship Between Number of Minimum Bands per 175 Person Mating Network and Social Costs

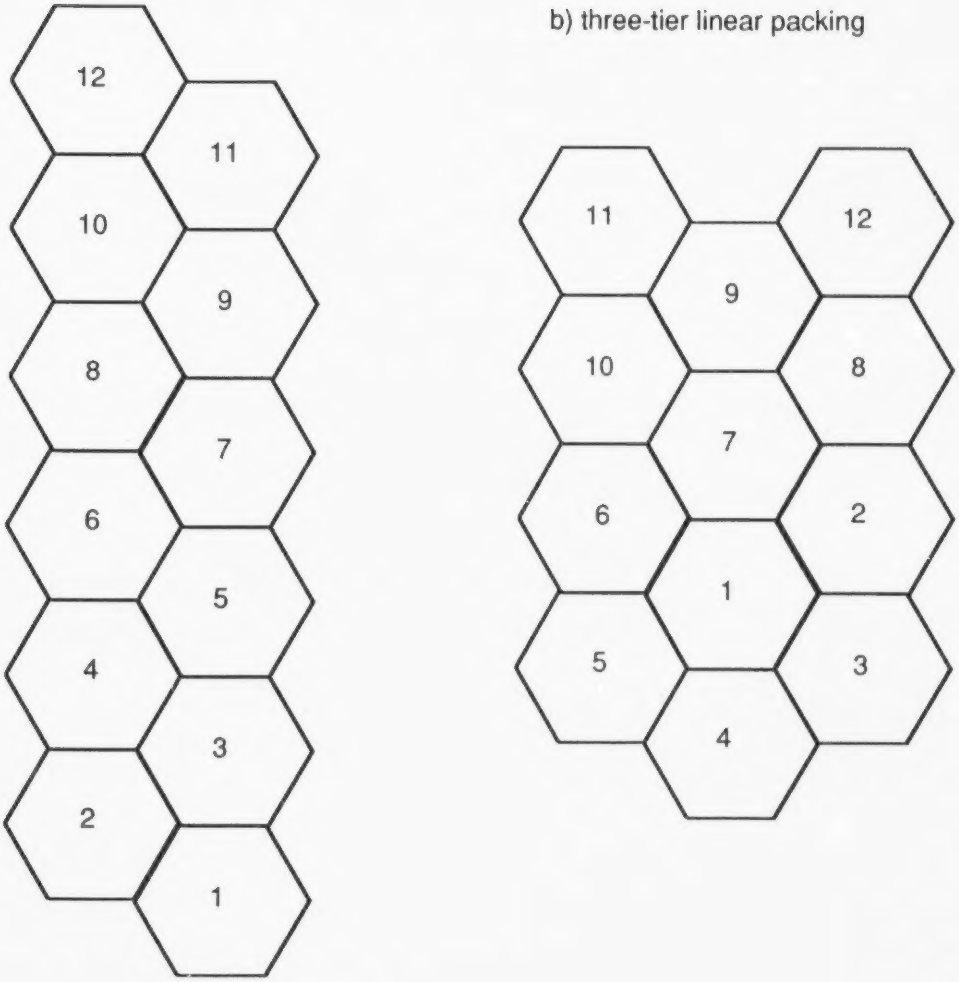
	Number of minimum bands per mating network	Minimum social cost measured in diameters	Minimum band range diameter	Total social cost for mating network	Average social cost per minimum band within network
25 member band	7	120	56 km	6720 km	960 km
20 member band	9	244	56 km	13,664 km	1518 km
15 member band	12	510	56 km	28,560 km	2380 km

To return to the ice-free corridor and the North Saskatchewan River valley, the important factor 13,000 years ago is that the shape of the corridor, constrained by high elevations on the west, and proglacial lakes on the east (at this time period just to the east of the study area), does not allow for ideal hexagonal packing. The constraints of the corridor allow only a linear arrangement of minimum bands (Fig. 7.12a).

As discussed earlier, social costs increase tremendously in linearly arranged systems, such that Wobst (1976) and Gamble (1986) doubted linearly constrained areas such as peninsulas or mountain-bounded sea coasts would be occupied until all alternative areas were at high densities. Using the method described above, average social costs for a two-tier linearly-arranged system as depicted in Fig. 7.12a can be calculated as 3267 km per minimum band. This is higher than the maximum sustainable social costs estimated above as 2380 km per minimum band.

Calculation of the exact range size and population density maxima that allow for maximum social costs per minimum band of 2380 km results in a range size of 1308 km^2 and a population density of $0.011 p/km^2$. Therefore, the maximum range size per minimum band that a two-tier linearly arranged system of 12 bands can sustain is 1308 km^2. This calculation means that to evaluate the environment in terms of both nutritional and social costs, environmental production in calories must be calculated per 1308 km^2 and again compared with minimum band daily nutritional requirements of 38,940 calories. These calculations are presented in column 7 of Table 7.6 and indicate that the environment 13,000 years ago was not viable when both nutritional and social factors are taken into consideration.

Figure 7.12 Optimal Band Packing in Linearly Constricted Mating Networks of 175 Persons with 12 Minimum Bands of 15 persons each


a) two-tier linear packing

b) three-tier linear packing

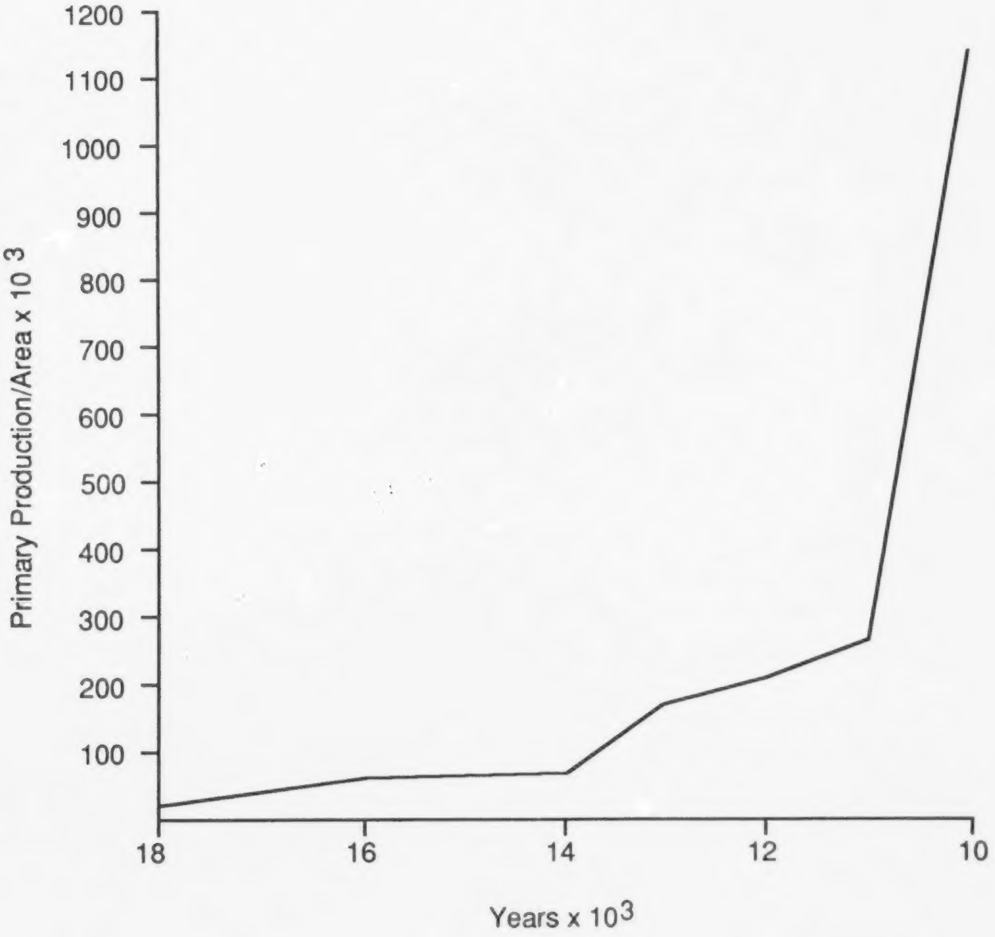
12
11
10
9
8
7
6
5
4
3
2
1
11
12
9
10
8
7
6
2
1
5
3
4

The value of 63,278 calories/day for 12,000 years ago, however, indicates 1.6 times the minimum requirement and thus suggests possible viability of the environment. Thus 12,000 years B.P. can be seen as a threshold time period in terms of social viability of hunter-gatherer populations within the ice-free corridor as exemplified by the upper North Saskatchewan drainage basin. The improvement in environmental productivity has a positive impact on human populations in other ways besides the simple increase in environmental productivity.

For example, the increase in productivity per area of land allows for three-tier packing of minimum bands as shown in Fig. 7.12b, or the supporting of larger bands in the minimum areas required, thus further decreasing potential social costs. Cultural options increase and social costs decrease further by 11,000 years ago, when bands of 25 are marginally possible within ranges of 1095 km^2, achieving ideal hexagonal packing and social costs of 638 km per minimum band.

The data and argument above, given my assumptions, demonstrate that the ice-free corridor, as represented by the upper North Saskatchewan drainage basin, could not have served as a viable human environment between about 18,000 and 12,000 years ago. Human viability is, however, increasingly more likely after 12,000 years ago, with conditions improving dramatically both nutritionally (Fig. 7.13) and socially (due to interaction of demographic variables) ca. 11,000 years ago, as demonstrated by the evidence of human occupation soon thereafter (e.g. Fedje 1987).

Figure 7.13 Relationships Between Primary Productivity and changing Study Area Size Through Time



8. Conclusion

8.1 Summary and Conclusions

The first three of the four stated objectives of this study have been met. The first objective was to establish the theoretical and historical context within which the concept of the ice-free corridor was developed as a passage for human entry into North America. Accordingly, the historical influences on the analysis and interpretation of the ice-free corridor were examined.

The second objective of this study was to develop a paleoecology of a region of the ice-free corridor of western Alberta at the ecosystem level, including abiotic and biotic processes, thus establishing physical context. Stratigraphic pollen analysis was done on cores from three sites in the upper North Saskatchewan drainage basin and local vegetation assemblages reconstructed. These local vegetation records, along with climatic and sedimentological data, were combined to provide a regional interpretation of the vegetational and environmental history of the region. Geological and geographic processes of full-, late-, and post-glacial times were examined and used to reconstruct the paleogeography of the study area. The paleogeography of the region provided the physical context within which the analysis of interrelationships between humans and the biotic resources of the environment were examined.

The third objective was to test the region's viability as a human environment through the analysis of relationships between the physical environment and social and biological factors. The human viability of the environment was analyzed by two different methods, general qualitative comparison and specific quantitative testing. Both methods established the unlikelihood of human survival in the corridor during full- or late-glacial times. Specific quantitative testing more precisely established nonviability of the environment prior to 12,000 years B.P., and stressed the importance of considering social factors in addition to nutrition. That is, an environment can theoretically be nutritionally viable and not socioculturally viable (which was the point behind considering nutrition separately first and bringing in social requirements later).

8.2 Implications for the Peopling of the New World

The fourth objective of this study was to examine the implications the reconstructed region has for the role of the ice-free corridor in the peopling of the New World. It was stated that a demonstration of nonviability of the corridor would imply that archaeological sites south of the borders of the ice sheets dating prior to or during full- and late-glacial times, are

1) evidence of migrations that occurred prior to the establishment of a nonviable environmental barrier,

2) more recent than their excavators believe,

3) nonarchaeological, or

4) remains left by people who arrived in the New World via another route.

It should be noted that none of the data or arguments presented here offer a means of choosing between the above options. These options must be considered as equally plausible explanations and evaluated individually. That is, the argument presented here that the upper North Saskatchewan drainage basin was a nonviable human environment between 18,000 and 12,000 years B.P. does not speak to the question of earlier arrivals (e.g., prior to closure of the corridor ca. 21,000 B.P.), or arrivals via other routes (although the method could certainly be applied to evaluation of other routes). It simply states that people didn't come through the ice-free corridor ca. 18,000 to 12,000 years ago. Thus the legitimacy of southern sites and alternate migration routes must still be established on separate grounds.

Furthermore, as mentioned earlier regarding the qualitative comparison of full-glacial environments around the world, the relationship between environmental conditions and human occupation has predictive power only in limiting environments. A demonstration of human viability of the environment within the corridor (as exemplified by the North Saskatchewan drainage basin) should by no means be interpreted as an assertion or indication of actual human presence, which must be established on the basis of archaeological data in secure, well-dated contexts.

Usually it is physical accessibility that is considered in evaluations of the ice-free corridor as a route for the first occupants of North America. Even when people are considered, it is usually in terms of whether "feeder" populations were available in northeastern Asia in the right time frame. However, even if the corridor was physically accessible and source populations existed in Beringia, it must be remembered that "satisfaction of the vital needs of any human population depends on the conditions of its environment and the population's ability to make use of what is available in the environment" (Henneberg and Ostoja-Zagorski 1984:44).

That is, there were still limiting factors to be dealt with, thresholds to be crossed, of a biological, technological, and sociological nature. Biological factors likely include efficient fat storage. A good case can be made for a fat storage bottleneck into the New World, that only those humans who could accumulate and maintain enough fat to make it through the late winter/early spring lean period passed their genes into the New World

(Weiss et al. 1984; Wendorf 1988; Relethford 1990).

Technological factors include such developments as bone marrow processing techniques for increasing fat intake, and fuel developments such as oil and wick lamps, important due to the scarcity of wood. Fuel was not considered in the above analysis as a limiting factor but it certainly would be an important factor in a treeless landscape. As mentioned earlier, while sleds are assumed to be an important development for increasing mobility (and thus decreasing mobility costs) in arctic areas; their utility is restricted to areas with significant snowfall, which excludes the arid ice-free corridor as reconstructed in this study. Social factors include the development of the ability to maintain ties over a distance, e.g., through "a network of alliances and the development of social systems that specify how the structure of resources should be exploited" (Gamble 1986:66).

Accordingly, the Paleoindian presence in North America may represent the first successful attempt after threshold conditions of the post-glacial ecosystem eased through a combination of environmental amelioration, technological and social innovation, and biological adaptation (leaving the possibility open of unsuccessful earlier migrations). Additionally, limiting environments (e.g., environments where resources are relatively low in predictability, diversity, and abundance) select for diversification. Specialization is not possible until a relatively high level of productivity has been reached. It is thus unlikely the earliest successful migrants to the New World were the specialized big-game hunters of archaeological mythology. The search for early migrants to the New World should instead be framed in the context of generalized cultural adaptations, which would not be possible until a certain level of environmental diversity was achieved.

As mentioned previously, the earliest documented archaeological sites in the corridor area, e.g., Vermillion Lakes, near Banff, Alberta (Fedje 1986, 1987) and Charlie Lake Cave, near Fort St. John, British Columbia (Fladmark et al. 1983) date to post-glacial times ca. 10,700 to 10,400 yr B.P. They offer no contradiction to the conclusion of this study that the corridor was a viable environment by 12,000 B.P. In addition it should be noted that alhough these sites represent the earliest documented occupation of the corridor, there is no guarentee they indicate immigration from the north. The lithic evidence and chronology could just as easily support an interpretation deriving them from populations to the south.

Finally, as Dillehay and Meltzer (1991:293) stated, "local models will differ in the details, but their broader implications about hunter-gatherer evolutionary processes must fit and have wider application." The methodology, theoretical approach, and conclusions presented in this study do have wider application than to simply the small region specifically considered here, and hopefully will make a contribution to broader understanding of hunter-gatherer adaptation.

Literature Cited

Adams, W.Y. (1973). The archaeologist as detective. In *Variation in anthropology: Essays in honor of John C. McGregor.* (D.W. Lathrap and J. Douglas, Eds.), pp. 17-29. Braun-Brunfield, Ann Arbor, Michigan.

Adams, R.W. and Duthie, H.C. (1976). Relationships between sediment chemistry and postglacial production rates in a small Canadian Lake. *Int. Revue ges Hydrobiol* 61:21-36.

Alberta Weather Centre. (1989). Conversation with employee.

Alden, W.C. and Stebinger, E. (1913). Prewisconsin glacial drift in the region of Glacier National Park, Montana. *Bulletin Geological Society of America* 24:529-572.

Alley, N.F. (1976). The palynology and paleoclimatic significance of a dated core of Holocene peat, Okanagan Valley, southern British Columbia. *Canadian Journal of Earth Sciences* 13:1131-1144.

Ames, K. M. (1987). Early Holocene adaptations on the southern Columbia Plateau. *20th Annual Canadian Archaeological Association Conference Programme and Abstracts*. Calgary, Alberta. p. 34.

Anderson, Douglas, D. (1968). A stone age campsite at the gateway to America. In *Early Man in America*. W.H. Freeman, San Francisco. pp. 29-38.

Anderson, P.M. and Brubaker, L.B. (1986). Modern pollen assemblages from northern Alaska. *Review of Paleobotany and Palynology* 46:273-291.

Anderson, P.M., Reanier, R.E., and Brubaker, L.B. (1988). Late Quaternary vegetational history of the Black River region in northeastern Alaska. *Canadian Journal of Earth Sciences* 25:84-94.

Anderson, P.M., Bartlein, P.J., Brubaker, L.B., Gajewski, K., and Ritchie, J.C. (1989). Modern analogues of late-Quaternary pollen spectra from the western interior of North America. *Journal of Biogeography* 16:573-596.

Andrews, J.T. (1973). The Wisconsin Ice Sheet: Dispersal centers, problems of rates of retreat and climatic implications. *Arctic and Alpine Research* 5:185-200.

Antevs, E. (1928). *The Last Glaciation*. American Geographic Society Research Series No. 17.

Antevs, E. (1929). Maps of the Pleistocene glaciations. *Bulletin Geological*

Society of America 40:631-720.

Antevs, E. (1934). Climaxes of the last glaciation in North America. *American Journal of Science* 28:304-311.

Antevs, E. (1935). The spread of aboriginal man to North America. *Geographical Review* 25:302-309.

Antevs, E. (1937). Climate and early man in North America. In *Early Man.* (GG.G. MacCurdy, Ed.), pp. 125-132. J.B. Lippincott, Philadelphia.

Antevs, E. (1945). Correlation of Wisconsin glacial maxima. *American Journal of Science* 243-A:1-39

Arno, S.F. (1984). *Timberline: Mountain and Arctic Forest Frontiers.* The Mountaineers, Seattle.

Bacon, C.R. (1983). Eruptive history of Mount Mazama and Crater Lake caldera, Cascade Range, U.S.A. *Journal of Volcanology and Geothermal Research* 18:57-115.

Bailey, G. and Gamble, C. The Balkans at 18,000 B.P.: the view from Epirus. In *The World at 18,000 B.P.: Volume 1, High Latitudes.* (O. Soffer and C. Gamble, Eds.), pp. 148-167. Unwin Hyman, London.

Baker, R.G. (1983). Holocene vegetational history of the western United States. In *Late Quaternary Environments of the United States.* (H.E.Wright, Ed.), Vol. 2, pp. 109-127. University of Minnesota, Minneapolis.

Baker, R.G. and Waln, K. (1985). Quaternary pollen records from the Great Plains and central United States. In. *Pollen Records of Late-Quaternary North American Sediments.* (V.M. Bryant and R.G. Holloway, Ed.), pp. 191-204. American Association of Stratigraphic Palynology Foundation, Dallas.

Barbour, M.G., Burk, J.H., and Pitts, W.D. (1980). *Terrestrial Plant Ecology.* Benjamin/Cummings Publishing Co., Inc., Menlo Park, California.

Barnosky, C.W. (1984). Late Pleistocene and early Holocene environmental history of southwestern Washington State, U.S.A. *Canadian Journal of Earth Sciences* 21:619-629.

Barnosky, C.W. (1985). Late Quaternary vegetation in the southwestern Columbia Basin, Washington. *Quaternary Research* 23:109-122.

Barnosky, C.W. (1989). Postglacial vegetation and climate in the northwestern great plains of Montana. *Quaternary Research* 31:57-73.

Barnosky, C.W., Grimm, E.C., and Wright, H.E., Jr. (1987a). Towards a postglacial history of the northern Great Plains: a review of the paleoecologic problems. *Annals of the Carnegie Museum* 56:259-273.

Barnosky, C.W., Anderson, P.M., and Bartlein, P.J. (1987b). The northwestern U.S. during deglaciation: vegetational history and paleoclimatic implications. In *North America and adjacent oceans during the last glaciation*. (W.F. Ruddiman and H.E. Wright, Jr., Eds.), pp. 289-321. Geological Society of America, Boulder.

Barry, R.G. (1982). Variability of the climate system. *American Quaternary Association Abstracts*. Seventh Biennial Conference, Seattle. pp. 2-3.

Bar-Yosef, O. (1987). Late Pleistocene Adaptations in the Levant . In *The Pleistocene Old World: Regional Perspectives*. (O.Soffer, Ed.) pp.219-236. Plenum, New York.

Bassett, I.J., Crompton, C.W., and Parmelee, J.A. (1978). *An Atlas of Airborne Pollen Grains and Common Fungus Spores of Canada*. Canadian Department of Agriculture Monograph No. 18, Ottawa.

Bay-Peterson, J.L. (1978). Animal exploitation in Mesolithic Denmark. In *The Early Postglacial Settlement of Europe*. (P. Mellars, Ed.), pp. 115-146. University of Pittsburgh Press, Pittsburgh.

Bayrock, L.A. (1965). Incomplete continental glacial record in Alberta. *INQUA Abstracts*. Seventh International Congress, Boulder. p. 18.

Beaton, J.M. (1991). Colonizing continents: some problems from Australia and the Americas. In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 209-230. CRC Press, Boca Raton, Florida.

Beaudoin, Alwynne B. (1989). *Annotated Bibliography Late Quaternary Studies in Alberta's Western Corridor 1950-1988*. Archaeological Survey of Alberta Manuscript Series No. 15.

Beget, J. (1987). Low Profile of the Northwest Laurentide Ice Sheet. *Arctic and Alpine Research* 19:81-88.

Belovsky, G.E. (1987) Hunter-gatherer foraging: a linear programing approach. *Journal of Anthropological Archaeology* 6:29-76.

Belovsky, G.E. (1988). An optimal foraging based model of hunter-gatherer population dynamics. *Journal of Anthropological Archaeology* 7:329-372.

Berggren, Greta. (1981). *Atlas of Seeds*. Berlings, Sweden.

Berglund, B.E., Ed. (1979). *Palaeohydrological Changes in the Temperate Zone in the last 15,000 years. Subproject B. Lake and Mire Environments.* International Geological Correlation Programme Project 158. Department of Quaternary Geology, Lund.

Berglund, B.E. (1986). Pollen analysis and pollen diagrams. In *Handbook of Holocene Palaeocology and Palaeohydrology*. (B.E. Berglund, Ed.), pp. 455-484. John Wiley & Sons Ltd, New York.

Binford, L.R. (1964). A consideration of archaeological research design. *American Antiquity* 29:425-441.

Binford, L.R. (1980). Willow smoke and dog's tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45:1-17.

Binford, L.R. (1981). *Bones: Ancient Men and Modern Myths.* Academic Press, New York.

Binford, L.R. (1982). The archaeology of place. *Journal of Anthropological Archaeology* 1:5-31.

Binford, L.R. (1991). There is always more we need to know. In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 275-286. CRC Press, Boca Raton, Florida.

Birks, H.J.B. (1973). Modern pollen rain studies in some arctic and alpine environments. In *Quaternary Plant Ecology*. (H.J.B. Birks and R.G. West, Eds.), pp. 143-168. Blackwell Scientific Publications, Oxford.

Birks, H.J.B. (1976). Late Wisconsinan vegetational history at Wolf Creek, Central Minnesota. *Ecological Monographs* 46:395-429.

Birks, H.J.B. (1977). Modern pollen rain and vegetation of the St. Elias Mountains, Yukon Territory. *Canadian Journal of Botany* 55:2367-2382.

Birks, H.J.B. (1980). The present flora and vegetation of the moraines of the Klutan Glacier, Yukon Territory, Canada: A study in plant Succession. *Quaternary Research* 14:60-86.

Birks, H.J.B. (1986). Late-Quaternary biotic changes in terrestrial and lacustrine environments with particular reference to north-west Europe. In *Handbook of Holocene Paleoecology and Palaeohydrology*. (B.E. Berglund, Ed.), pp. 3-65. John Wiley and Sons, New York.

Birks, H.J.B. and Birks, H.H. (1980). *Quaternary Paleoecology*. Edward Arnold, London.

Birks, H.J.B., Webb, T., and Berti, A.A. (1975). Numerical analysis of surface samples from central Canada: a comparison of methods. *Review of Paleobotany and Palynology* 20:133-169.

Bjorck, S., and Hakansson, S. (1982). Radiocarbon dates from Late Weichselian lake sediments in south Sweden as a basis for chronostratigraphic subdivision. *Boreas* 11:141-150.

Bliss, L.C., Ed. (1977). *Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem*. The University of Alberta Press, Edmonton.

Bliss, L.C. (1984). Arctic Ecosystems: their structure, function, and herbivore carrying capacity.

Bliss, L.C., Courtin, G.M., Pattie, D.L., Riewe, R.R., Whitfield, D.W.A., and Widden. (1973). Arctic tundra ecosystems. *Annual Review of Ecology and Systematics* 4:359-399.

Bobrowsky, P.T. (1988). Ice free conditions in the northern Canadian Cordillera at 18 ka and timing of the late Wisconsinan. *American Quaternary Association, Program and Abstracts*, 10th Biennial Meeting, p. 108.

Bobrowsky, P.T. (1989). *Late Cenozoic Glaciation of the Northern Rocky Mountain Trench, British Columbia*. Unpublished Ph.D. dissertation, University of Alberta.

Bobrowsky, P.T., Levson, V., Liverman, D.G.E., and Rutter, N.W. (1987). *Quaternary Geology of Northwestern Alberta and Northeastern British Columbia*. Excursion Guidebook A-24, International Union for Quaternary Research, XIIth Congress, Ottawa.

Bobrowsky, P.T., Catto, N.R., Brink, J.W., Gibson, T.H., Spurling, B.E., and Rutter, N.W. (1990). Geoarchaeology of western and northern Canada. *Geological Society of America Centennial Special Volume. No. 4*, pp. 87-122.

Bowdler, S. (1981). Hunters in the highlands: Aboriginal adaptations in the eastern Australian Uplands. *Archaeol. Oceania* 16:99-111.

Boydell, A.N. (1978). *Multiple glaciations in the foothills, Rocky Mountain House area, Alberta*. Alberta Research Council Bulletin 36.

Boydell, A.N., Bayrock, L.A., and Reimchen, T.H.F. (1974) Surficial Geology, Rocky Mountain House. NTS 83B Map, 1:250,000. Alberta Research Council, Edmonton.

Bradbury, J.P. and Whiteside, M.C. (1980) Paleolimnology of two lakes in the Klutan Glacier region, Yukon Territory, Canada. *Quaternary Research* 14:149-168.

Bradley, R.S. (1985). *Quaternary Paleoclimatology: Methods of Paleoclimatic Reconstruction*. Allen & Unwin, Boston.

Brierly, J.A. (1990). Origin of surficial materials of an unglaciated area in southwest Alberta. *CAG/ACG Abstracts*. Canadian Association of Geographers Annual Meeting, Edmonton, Alberta.

Bright, R.C. (1966). Pollen and seed stratigraphy of Swan Lake, southeastern Idaho. *Tebiwa* 9:1-47.

Broccoli, A.J. and Manabe, S. (1987). The effects of the Laurentide ice sheet on North American climate during the last glacial maximum. *Geographie physique et Quaternaire* XLI:291-299.

Broecker, W.S., Thurber, D.L., Goddard, J., Ku, T., Matthews, R.K., and Meslella, K.J. (1968). Milankovitch Hypothesis is supported by precise dating of coral reefs and deep sea sediments. *Science* 159:297-300.

Brown, J.A. (1987). The Case for the Regional Perspective: A New World View. In *The Pleistocene Old World: Regional Perspectives*. (O.Soffer, Ed.), pp. 365-375. Plenum, New York.

Brown, R.J.E. and Pewe, T.L. (1973). Distribution of permafrost in North America and its relationship to the environment: A review, 1963-1973. In *Permafrost: North American Contribution to the Second International Conference*. pp. 71-100. National Academy of Sciences, Washington, D.C.

Bryan, A.L. (1968). Some problems and hypotheses relative to the early entry of man into America*Anthropologica* 10(2):157-177.

Bryan, A.L. (1969a). Early man in America and the late Pleistocene chronology of western Canada and Alaska. *Current Anthropology* 10:339-365.

Bryan, A.L. (1969b). Early man in western Canada: A critical review. In *Early Man in Western North America*. (C. Irwin-Williams, Ed.), Eastern New Mexico University Contributions in Anthropology 1(4):70-77.

Bryan, Kirk. (1941). Geologic antiquity of man in America. *Science* 93:505-514.

Bryson, R.A., and Wendland, W.M. (1967). Tentative climatic patterns for some late-glacial and post-glacial episodes in central North America. In *Life, land, and water, Lake Agassiz region*. (W.J. Mayer-Oakes, Ed.), pp. 271-298. Department of Anthropology Occasional Paper 1, University of Manitoba,Winnipeg.

Budd, A.C. (1987). *Budd's flora of the Canadian prairie provinces*. Revised and enlarged by J. Looman and K.F. Best. Agriculture Canada.

Burch, E.S., and Correll, T.C. (1972). Alliance and conflict: inter-regional relations in North Alaska. In *Alliance in Eskimo Society*. (D.L. Guempe, Ed.), pp. 17-39. University of Washington Press, Seattle.

Burns, J.A. (1984). *Late Quaternary palaeoecology and zoogeography of southwestern Alberta: vertebrate and palynological evidence from two Rocky Mountain caves*. Unpublished Ph.D. dissertation, Department of Zoology, University of Toronto.

Burns, J.A. (1989). *Late Mid-Wisconsinan paleoecology of Alberta - Contributions from vertebrate paleontology*. Program and Abstracts, CANQUA 1989. p. 28.

Burns, J.A. (1990). Paleontological perspectives of the ice-free corridor. In *Megafauna and man: Discovery of America's heartland*. (L.D. Agenbroad, J.I. Mead, and L.W. Nelson, Eds.), The Mammoth Site of Hot Springs, South Dakota, Inc. Scientific Papers, Volume 1.

Bushnell, G. (1968). *The First Americans*. McGraw-Hill, New York.

Bushnell, G. and McBurney, C. (1959). New World origins seen from the Old World. *Antiquity* 33 :93-101.

Butzer, K.W. (1971). *Environment and Archaeology: An Ecological Approach to Prehistory*. Aldine, New York.

Butzer, K.W. (1982). *Archaeology as human ecology: Method and Theory for a contextual approach*. Cambridge University Press, Cambridge.

Butzer, K.W. (1988). A "marginality" model to explain major spatial and temporal gaps in the Old and New World Pleistocene settlement records. *Geoarchaeology* 3:193-203.

Butzer, K.W., (1990). A human ecosystem framework for archaeology. In *The Ecosystem Approach in Anthropology: From Concept to Practice*. (E.F. Moran, Ed.), pp. 91-130. University of Michigan Press, Ann Arbor.

Butzer, K.W. (1991). An Old World perspective on potential Mid-Wisconsinan settlement of the Americas. In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 137-156. CRC Press, Boca Raton, Florida.

Byers, D.S. (1957). The Bering bridge - some speculations. *Ethnos* 22:20-26.

Calhoun, F.H. (1906). *The Montana lobe of the Keewatin ice sheet*. U.S.G.S.

Professional Paper #50. U.S. Government Printing Office, Washington, D.C.

Canby, T.Y. (1979). The search for the first Americans. *National Geographic* 156:330-345.

Capps, S.R. (1931). *Glaciation in Alaska*. U.S.G.S. Professional Paper #170-A. U.S. Government Printing Office, Washington, D.C. (Price 15 cents!)

Carrara, P.E., Wilcox, R.E., and Short, S.K. (1986). Deglaciation of the mountainous region of northwestern Montana east of the Continental Divide. *Arctic and Alpine Research* 18:317-325.

Cashdan, E., Ed. (1990). *Risk and Uncertainty in Tribal and Peasant Economics*. Westview Press, Boulder, Colorado.

Casteel, R.W. (1972). Two static maximum-population-density models for hunter-gatherers: A first approximation. *World Archaeology* 4:19-40.

Catto, N.R. (1986). *Quaternary sedimentology and stratigraphy, Peel Plateau and Richardson Mountains, Yukon and N.W.T.* Unpublished Ph.D. dissertation, University of Alberta.

Catto, Norm and Carole Mandryk. (1990). Geology of the Postulated Ice-Free Corridor. In *Megafauna and Man: Discovery of America's Heartland*. (L.D. Agenbroad, J.I. Mead and L.W. Nelson, Eds.),The Mammoth Site of Hot Springs, South Dakota, Inc. Scientific Papers, Volume 1. pp. 80-85. The Mammoth Site of Hot Springs, South Dakota, Inc. and Northern Arizona University, Hot Springs, South Dakota and Flagstaff, Arizona.

Cawker, K.B. (1983). Fire history and grassland vegetation change: three pollen diagrams from southern British Columbia. *Canadian Journal of Botany* 61:1126-1139.

Ceram, C.W. (1971). *The First American: A Story of North American Archaeology*. Harcourt, Brace, Jovanovich, New York.

Chamberlin, T.C. (1894). Glacial phenomena of North America. In *The Great Ice Age* (J. Geike, Ed.), pp. 724-776. 3rd Edition, Edward Stanford, London.

Chard, C.S. (1958). New World migration routes. *Anthropological Papers of the University of Alaska* 7:23-26.

Chard, C.S. (1959). New World Origins: A reappraisal. *Antiquity* 33:44-49.

Chard, C. (1974). *Northeast Asia in Prehistory*. University of Wisconsin Press, Madison.

Chen, C. and Olsen, J.W. (1990). China at the Last Glacial Maximum. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 276-295. Unwin Hyman, London.

Christensen, E.A. (1979). Wisconsin deglaciation of southern Saskatchewan and adjacent areas. *Canadian Journal of Earth Sciences* 16:913-938.

Church, M. (1976). Stream regime in cold and warm deserts. *American Quaternary Association Program and Abstracts*, pp. 36-39.

Churcher, C.S. (1984). Faunal correlations of Pleistocene deposits in western Canada. In *Correlation of Quaternary Chronologies* (W.C. Mahaney. Ed.), pp. 145-158. Geo Books, Norwich.

Churcher, C.S. and Wilson, M.C. (1979). Quaternary mammals from the eastern Peace River district, Alberta. *Journal of Paleontology* 53:71-76.

Clark, G. (1969). *World Prehistory*. Cambridge University Press, Cambridge.

Clark, G. (1988). The Upper Paleolithic of North East Asia and its relevance to the first Americans: a personal view. *Current Research in the Pleistocene* 5:3-7.

Clarke, A.H. (1981). *The Freshwater Molluscs of Canada*. National Museum of Natural Sciences, National Museums of Canada, Ottawa.

Clayton, L. (1964). Karst topography on stagnant glaciers. *Journal of Glaciology* 5:107-112.

Clayton, L. and Moran, S.R. (1974). A glacial process-form model. In *Glacial Geomorphology* (D.R. Coates, Ed.), pp. 89-119. State University of New York, Binghamton.

CLIMAP Project Members. (1976). The surface of the ice age earth. *Science* 191:1131-1144.

Cole, K.L. (1990). Reconstruction of past desert vegetation along the Colorado River using packrat middens. *Paleogeography, Paleoclimatology, Paleoecology* 76:349-366.

Coleman, A.P. (1909). The drift of Alberta and the relations of the Cordilleran and Keewatin ice sheets. *Trans. Royal Society of Canada* 3(4):3-12.

Colinvaux, P.A. (1964). The environment of the Bering Land Bridge. *Ecological Monographs* 34:297-329.

Collier, J. (1947). *The Indians of the Americas*. W.W. Norton & Co., New York.

Conkey, M.W. (1987). Interpretative problems in hunter-gatherer regional studies. In *The Pleistocene Old World: Regional Perspectives*. (O.Soffer, Ed.) pp.63-77. Plenum, New York.

Copi, I.M. (1972). *Introduction to Logic*. 4th Edition. Macmillan Company, New York.

Cormack, R.G.H. (1977). *Wildflowers of Alberta*. Hurtig Publishers, Edmonton.

Cosgrove, R., Allen, J., and Marshall, B. (1990). Palaeo-ecology and Pleistocene human occupation in south central Tasmania. *Antiquity* 64:59-78.

Courbin, Paul. (1988). *What is Archaeology?: An Essay on the Nature of Archaeological Research*. Translated by P. Bahn. The University of Chicago Press, Chicago.

Critchfield, H.J. (1983). *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Croll, J. (1867). On the eccentricity of the Earth's orbit, and its physical relations to the glacial epoch. *Phil. Mag.* 33:119-131.

Crumley, C.L. (1979). Three locational models: an epistemological assessment for anthropology and archaeology. In *Advances in Archaeological Method and Theory*. (M.B. Schiffer, Ed.), pp. 141-173. Academic Press, New York.

Crumley, C.L. and Marquardt, W.H. (1990). Landscape: a unifying concept in regional analysis. In *Interpreting Space: GIS and archaeology*. (K.M.S. Allen, S.W.Green, and E.B.W. Zubrow, Eds.), pp. 73-79. Taylor and Francis, London.

Cwynar, L.C. (1982). A Late-Quaternary vegetation history from Hanging Lake, northern Yukon. *Ecological Monographs* 52:1-24.

Cwynar, L.C., and Ritchie, J.C. (1980). Arctic steppe-tundra: a Yukon perspective. *Science* 208:1375-1377.

Czudek, T. and Demek, J. (1970). Thermokarst in Siberia and its influence on the development of lowland relief. *Quaternary Research* 1:103-120.

Dancey, W.S. (1981). *Archaeological Field Methods*. Burgess Publishing, Minneapolis, Minnesota.

Dansgaard,W., Johnsen, S.J., Clausen, H.B., and Langway, C.C. (1971). Climatic record revealed by the Camp Century Ice Core. In *The Late Cenezoic Glacial Ages*. (K.K. Turekian, Ed.), pp. 37-57. Yale University Press, New Haven.

David, P.A. (1981). Stabilized dune ridges in northern Saskatchewan. *Canadian Journal of Earth Sciences* 18:286-310.

Davis, M.B. (1967). Pollen accumulation rates at Rogers Lake, Connecticut, during late- and post-glacial time. *Review of Paleobotany and Palynology* 2:219-230.

Davis, M.B., Brubaker, L.B. and Webb, T. (1973). Calibration of absolute pollen influx. In *Quaternary Plant Ecology*. (H.J.B. Birks and R.G. West, Eds.), pp. 9-25. Wiley, New York.

Davis, M.B., Moeller, R.E. and Ford, J. (1984) Sediment focusing and pollen influx. In *Lake Sediments and Environmental History*. (E.Y. Haworth and J.W.G. Lund, Eds.), pp. 261-293. University of Minnesota Press, Minneapolis.

Davis, R.S. (1990). Central Asian hunter-gatherers at the Last Glacial Maximum. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 266-275. Unwin Hyman, London.

Dawson, G.M. (1890). On the later physiographical geology of the Rocky Mountain region of Canada, with special reference to changes in elevation and to the history of the Glacial Period. *Trans. Royal Society of Canada* 8(4):3-74.

Dean, W. E. (1974). Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: Comparison with other methods. *Journal of Sedimentary Petrology* 44:242-248.

De Boor, C. (1978). *A practical guide to splines*. Springer-Verlag, New York.

de Laguna, F. (1936) An archaeological reconnaissance of the Middle and Lower Yukon Valley, Alaska. *American Antiquity* 2:6-12.

Delorme, L.D., Zoltai, S.C., and Kalas, L.L. (1977). Freshwater shelled invertebrate indicators of paleoclimate in northwestern Canada during late glacial times. *Canadian Journal of Earth Sciences* 14:2029-2046.

Dennell, R. (1983). *European Economic Prehistory*. Academic Press, London.

Denton, G.H. (1970). Late Wisconsin glaciation in northwestern North

America: Ice recession and origin of paleo-indian Clovis complex. *AMQUA Abstracts.*, pp. 34-35.

Diamond, J.M. (1987). Who were the first Americans? *Nature* 329:580-581.

Dillehay, T.D. and Meltzer, D.J. (1991). Finale: Proceses and prospects.In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 287-294. CRC Press, Boca Raton, Florida.

Dincauze, D.F. (1981). Paleoenvironmental reconstruction in the Northeast: the art of multidisciplinary science. In *Foundations of Northeast Archaeology*. (D.R. Snow, Ed.), pp. 51-96. Academic Press, New York.

Dincauze, D.F. (1984). An archaeo-logical evaluation of the case for pre-Clovis occupations. *Advances in World Archaeology* 3:275-323.

Dincauze, D.F. (1987). Strategies for paleoenvironmental reconstruction in archaeology. *Advances in Archaeological Method and Theory* 11:255-336.

Dodson, J.R. (1989). Late Pleistocene vegetation and environmental shifts in Australia and their bearing on faunal extinctions. *Journal of Archaeological Science* 16:207-217.

Donn, W.L., and Ewing, M. (1968). The theory of an ice-free Arctic Ocean. *Meteorological Monographs* 8:100-105.

Dove, D.E. (1984). *Prehistoric subsistence and population change along the lower Agua Fria River, Arizona: A model simulation.* Arizona State University Anthropological Research Papers No. 32.

Driscoll, F.G., Jr. (1980). Wastage of the Klutan ice-cored moraines, Yukon Territory, Canada. *Quaternary Research* 14:31-49.

Driver, H.E. (1969). *Indians of North America.* University of Chicago Press, Chicago, Illinois.

Driver, J.C. (1988). Late Pleistocene and Holocene vertebrates and paleoenvironments from Charlie Lake Cave, northeast British Columbia. *Canadian Journal of Earth Sciences* 25:1545-1553.

Duk-Rodkin, A. (1989). Types of merger between montane and Laurentide ice during the Late Wisconsinan in the Mackenzie mountains compared to modern examples in Milne Glacier and ice shelf. *CANQUA Abstracts*, p. 30., Edmonton, Alberta.

Dumond, D.E. (1980). The archaeology of Alaska and the peopling of America. *Science* 209:984-991.

Dyke, A.S., and Prest, V.K. (1987). Late Wisconsinan history of the

Laurentide ice sheet. *Geographie Physique et Quaternaire* XLI:237-263.

Dyson-Hudson, R. and Smith, E.A. (1978). Human territoriality: an ecological reassessment. *American Anthropologist* 80:21-41.

Eidlitz, K. (1969). *Food and emergency food in the Circumpolar zone*. Studia Ethnographica Upsaliensia 32. Upsala University Press, Upsala.

Edwards, M.E. (1988). Pollen size of Betula species in Alaska. *American Quaternary Association Program and Abstracts*, p. 65.

Environment Canada. (1982). *Canadian climatic normals: Temperature and precipitation, 1951-1980, Prairie Provinces*. Atmospheric Environment Service, Toronto.

Embleton, C. and King, C.A.M. (1975). *Glacial Geomorphology*. Edward Arnold, London.

Emerson, D. (1977). *The Surficial Geology of the Cooking Lake Moraine, East-Central Alberta, Canada*. Unpublished M.Sc. Thesis, Department of Geology, University of Alberta.

Faegri, K., and Iverson, J. (1975). *Textbook of pollen analysis*. 3rd Edition. Hafner Press, New York.

Fagan, B.M. (1987). *The Great Journey: The peopling of ancient America*. Thames and Hudson, London.

Farrand, W.R. (1970). Remarks on glacial and climatic events along the southern margin of the Laurentide ice sheet. *AMQUA Abstracts*, pp. 43-44.

Fedje, D.W. (1986). Banff archaeology 1983-1985. In *Eastern slopes prehistory: selected papers*. (B.M. Ronaghan, Ed.), pp. 25-62. Archaeological Survey of Alberta Occasional Paper 30. Alberta Culture and Multiculturalism, Edmonton.

Fedje, D.W. (1987). *Vermillion Lakes archaeology and paleoecology: Trans-Canada highway mitigation in Banff National Park*. Manuscript on file, Archaeological Research Services, Canada Parks Service, Western Region, Calgary.

Fedje, D.W., White, J.M. and Robinson, S. (1985). *Vermillion Lakes archaeology, Trans Canada Highway, Mitigation in Banff National Park*. Staff Report on file, Parks Canada, Calgary.

Fiedel, S.J. (1987). *Prehistory of the Americas*. Cambridge University Press, Cambridge.

Figgins, J.D. (1927). The antiquity of man in America. *Natural History* 27(3):229-239.

Fillion, R.H., Hardy, I.A., Wagner, F.J.E., Andrews, J.T., and Josenhans, H.W. (1981). *Labrador Shelf: shell and total organic matter ^{14}C date discrepancies*. Geological Survey of Canada Paper 81-1B, pp. 105-111.

Fitzhugh, W.W. (1972). *Environmental Archaeology and Cultural Systems in Hamilton Inlet, Labrador: A Survey of the Central Labrador Coast from 3000 B.C. to the Present*. Smithsonian Contributions to Anthropology No. 16. Smithsonian Institution Press, Washington, D.C.

Fix, A.G. (1981). Endogamy in settlement populations of Semai Senoi: potential mate pool analysis and simulation. *Social Biology* 28:62-74.

Fladmark, K.R. (1983). Times and places: environmental correlates of Mid-to-Late Wisconsinan human population expansion in North America. In *Early Man in the New World* (R. Shutler, Ed.), pp. 13-41. Sage Publications, Beverly Hills.

Fladmark, K.R. (1986). Getting one's Berings. *Natural History* 95(11):8-17.

Fladmark, K.R., Driver, J.C. and Alexander, D. (1988). The Paleoindian component at Charlie Lake Cave (HbRf39), British Columbia. *American Antiquity* 53:371-384.

Flint, R.F. (1942). Glacier thinning during deglaciation. *American Journal of Science* 240:113-136.

Flood, J. (1976). Man and ecology in the highlands of southeastern Australia. In *Tribes and Boundaries in Australia*. (N. Peterson, Ed.), pp. 30-49. Australian Institute of Aboriginal Studies, Australia.

Florin, M.B. and Wright, H.E.,Jr. (1969). Diatom evidence for the persistence of stagnant glacial ice in Minnesota. *The Geological Society of America, Bulletin* 80:695-704.

Forbis, R.G. (1975), The paleoamericans. In *North America* (S. Gorenstein, Ed.), pp.17-35. St. Martin's Press, New York.

Fowler, C.S., Compiler and Ed. (1989). *Willard Z. Park's Ethnographic Notes on the Northern Paiute of Western Nevada, 1933-1940, Vol. 1*. University of Utah Anthropological Papers No. 114, University of Utah Press, Salt Lake City.

Fullerton, D.S. and Colton. R.B. (1986). Stratigraphy and correlation of the glacial deposits on the Montana plains. In *Quaternary glaciations in the northern hemisphere* (V. Sibrava, D.Q. Bowen, and G.M. Richmond, Eds.), pp.69-82. *Quaternary Science Reviews* 5.

Funder, S., and Abrahamsen, N. (1988). Palynology in a polar desert, eastern north Greenland. *Boreas* 17:195-207.

Gal-Chen, Tzvi. (1982). Approaches to mathematical modeling of the steppe-tundra paleoclimate. In *Paleoecology of Beringia*. (D.M. Hopkins, J.V. Matthews, Jr., C.E. Schweger, and S.B. Young, Eds.), pp.205-218. Academic Press, New York.

Gamble, C. (1984). Regional variation in hunter-gatherer strategy in the Upper Pleistocene of Europe. In *Hominid Evolution and Community Ecology*. (R. Foley, Ed.), pp. 237-260). Academic Press, New York.

Gamble, C. (1986). *The Palaeolithic Settlement of Europe*. Cambridge University Press, Cambridge.

Gamble, C. (1987). Man the shoveler: alternative models for middle Pleistocene colonization and occupation in northern latitudes. In *The Pleistocene Old World: regional perspectives*. (O. Soffer, Ed.), pp. 81-98. Plenum, New York.

Gamble, C. and Soffer, O., Eds. (1990a). *The World at 18,000 B.P.: Volume 2, Low Latitudes*. Unwin Hyman, London.

Gamble, C. and Soffer, O. (1990b). Pleistocene polyphony: the diversity of human adaptations at the Last Glacial Maximum. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 1-23. Unwin Hyman, London.

Garrett, W.E. (1988). Where did we come from? *National Geographic* 174(4):434-437.

Gennett, J.A. and Baker, R.G. (1986). A Late Quaternary pollen sequence from Blacktail Pond, Yellowstone National Park, Wyoming, U.S.A. *Palynology* 10:61-71.

Gero, J.M. (1985) Socio-politics of archaeology and the woman-at-home ideology. *American Antiquity* 50:342-350.

Gero, J. and Root, D. (1990). Public presentations and private concerns: archaeology in the pages of National Geographic. In *The politics of the past*. (P. Gathercote and D. Lowenthal, Eds.), pp.19-37. Unwin Hyman, London.

Getis, A., Getis, J., and Fellmann, J. (1985). *Human Geography: Culture and Environment*. MacMillan Publishing Co., New York.

Gibson, T.H. (1985). *Pollen data log and analysis program VI*. Unpublished program for Apple 2e, on file Paleoenvironmental Lab, Anthropology

Department, University of Alberta.

Giddings, J.L. (1954). Early man in the Arctic. *Scientific American* 190:82-88.

Gladwin, H.S. (1937). *Excavations at Snaketown: II, comparisons and theories.* Medallion Papers XXVI. Gila Pueblo, Globe, Arizona.

Goddard, P.E. (1927). Facts and theories concerning Pleistocene man in America. *American Anthropologist* 29:262-266.

Gordon, A.D. and Birks, H.J.B. (1972). Numerical methods in Quaternary paleoecology I: Zonation of pollen diagrams. *New Phytologist* 71:961-969.

Gordon, B.H.C. (1975). *Of Men and Herds in Barrenland Prehistory.* National Museum of Man Mercury Series, Archaeological Survey of Canada Paper No. 28.

Gravenor, C.P. and Kupsch. (1959). Ice-disintegration features in western Canada. *Journal of Geology* 67:48-64.

Green, S.W. and Perlman, S.M. (1985). Frontiers, Boundaries, and Open Social Systems. In *The Archaeology of Frontiers and Boundaries.* (S.W. Green and S.M. Perlman, Eds.), pp. 3-13. Academic Press, New York.

Greiser, S.T. (1985). Predictive Models of Hunter-Gatherer Subsistence and Settlement Strategies on the Central High Plains. *Plains Anthropologist* Memoir 20.

Gribben, J. (1978). The search for cycles. In *Climatic Change* (J. Gribben, Ed.), pp.139-149. Cambridge University Press, Cambridge.

Grichuk, V.P. (1984). Late Pleistocene vegetation history. In *Late Quaternary Environments of the Soviet Union.* (A.A. Velichko, Ed., H.E. Wright and C.W. Barnosky, Eds., of English language version), pp. 155-178. University of Minnesota Press, Minneapolis.

Griffen, J.B. (1960). Some prehistoric connections between Siberia and America. *Science* 131:801-812.

Griffen, J.B. (1967). Eastern North American archaeology: A summary. *Science* 156:175.

Grimes, J.R., Eldridge, W., Grimes, B.G., Vaccaro, A., Vaccaro, F., Vaccaro, N., and Orsini, A. (1984). Bull Brook II. *Archaeology of Eastern North America* 12:159-183.

Gryba, E. (1983). *Sibbald Creek: 11,000 years of human utilization of the southern Alberta foothills.* Archaeological Survey of Alberta Occasional

Paper 22. Alberta Culture, Edmonton.

Guralink, D.B. (1978). *Webster's New World Dictionary*. 2nd College Edition. William Collins and World Publishing Company.

Guthrie, R.D. (1966). The extinct Wapiti of Alaska and Yukon territory. *Canadian Journal of Zoology* 44:45-57.

Guthrie, R.D. (1968). Paleoecology of the large-mammal community in interior Alaska during the late Pleistocene. *American Midland Naturalist* 79:346-363.

Guthrie, R.D. (1990a). *Frozen Fauna of the Mammoth Steppe: The Story of Blue Babe*. University of Chicago Press, Chicago.

Guthrie, R.D. (1990b). Late Pleistocene faunal revolution - A new perspective on the extinction debate. In *Megafauna and Man: Discovery of Americas Heartland*. (L.D. Agenbroad, J.I. Mead, and L.W. Nelson, Eds.), pp. 42-53. The Mammoth Site of Hot Springs, South Dakota, Inc. Scientific Papers, Volume 1.

Haag, W.G. (1962). The Bering Straight land bridge. *Scientific American* 206:112-123.

Habgood, S. (1985). *A key to pollen and spores of Alberta*. 3rd Edition revised by E. Simons. Unpublished manuscript on file, Paleoenvironmental Studies Laboratory, University of Alberta, Edmonton.

Halstead, P. and O'Shea, J. (1989). Introduction: cultural responses to risk and uncertainty. In *Bad Year Economics*. (P. Halstead and J. O'Shea, Eds.), pp. 1-7, Cambridge University Press, Cambridge.

Hansen, B.C.S., and Wright, H.E. Jr. (1987). The modern pollen rain of North Dakota, U.S.A. *Pollen et Spores* 29:167-184.

Hardy, W.G. (1971). *Alberta: A Natural History*. M.G. Hurtig Publishers, Edmonton.

Hare, F.K. (1976). Late Pleistocene and Holocene climates: some persistent problems. *Quaternary Research* 6:507-517.

Harington, C.R. (1978). Quaternary vertebrate faunas of Canada and Alaska and their suggested chronological sequence. *Syllogeus* 15. National Museums of Canada, Ottawa. (105pp).

Harris, S.A. and Boydell, A.N. (1972). Glacial history of the Bow River and Red Deer River areas and the adjacent foothills. In *Mountain Geomorphology*. (H.O. Slaymaker and H.J. McPherson, Eds.), pp.47-53. Tantalus Press, Vancouver.

Hartshorn, J.H. (1952). Superglacial and proglacial geology of the Malaspina Glacier, Alaska, and its bearing on glacial features of New England. *Geological Society of America Bulletin* 63:1259-1260.

Hassan, Fekri. (1981). *Demographic Archaeology*. Academic Press, New York.

Hayden, B. (1981a). Subsistence and ecological adaptations of modern hunter-gatherers. In *Omnivorous primates: gathering and hunting in human evolution*. (R.S.O. Harding and G. Teleki, Eds.), pp. 344-421. Columbia University Press, New York.

Hayden, B. (1981b). Research and development in the Stone Age: technological transitions among hunter-gatherers. *Current Anthropology* 22:519-542.

Hayden, B., Chisholm, B., and Schwarcz. (1987). Fishing and foraging: marine resources in the Upper Paleolithic of France. In *The Pleistocene Old World: regional perspectives*. (O. Soffer, Ed.),pp. 279-291. Plenum, New York.

Hays, J.D., Imbrie, J, and Shackleton, N.J. (1976). Variations in the earth's orbit: pacemaker of the Ice Ages. *Science* 194:1121-1132.

Haynes, C.V. (1964). Fluted projectile points: their age and dispersion. *Science* 145:1408-1413.

Haynes, C.V. (1966). Elephant hunting in North America. In *Early Man in America*. pp. 44-57. W.H. Freeman, San Francisco.

Haynes, C.V. (1971). Time, environment, and Early Man. *Arctic Anthropology* 8(2):3-14.

Henneberg, M. and Ostoja-Zagorski, J. (1984). Use of a general ecological model for the reconstruction of prehistoric economy: the Halstatt period culture of northwestern Poland. *Journal of Anthropological Archaeology* 3:41-78.

Heusser, C.J. (1983). Vegetational history of the northwestern United States including Alaska In *Late Quaternary environments of the United States, Vol. 1, The Late Pleistocene*. (S.C. Porter, Ed.), pp.239-258. University of Minnesota Press, Minnesota.

Hibbert, D. (1982). History of the steppe-tundra concept. In *Paleoecology of Beringia*. (D.M. Hopkins, J.V. Matthews, Jr., C.E. Schweger, and S.B. Young, Eds.). pp. 153-156. Academic Press, New York.

Hickman, M. and Schweger, C.E. (1991). A palaeoenvironmental study of

Fairfax Lake, a small lake situated in the Rocky Mountain Foothills of west-central Alberta. *Journal of Paleolimnology* 6:1-15.

Hickman, M., Schweger, C.E., and Habgood, T. (1984). Lake Wabamun, Alberta: a paleoenvironmental study. *Canadian Journal of Botany* 62:1438-1465.

Hoganson, J.W. and Ashworth, A.C. (1992). Fossil Beetle evidence for climatic change 18,000-10,000 Years B.P. in South-Central Chile. *Quaternary Research* 37:101-116.

Hopkins, D.M. (1949). Thaw, lakes and thaw sinks in the Imunuk Lake area, Seward Peninsula, Alaska. *Journal of Geology* 57:119-131.

Hopkins, D.M., Matthews, J.V. Jr., Schweger, C.E., and Young, S.B., (Eds.), (1982). *Paleoecology of Beringia*. Academic Press, New York.

Hoppe, G. (1952). Hummocky moraine regions - with special reference to the interior of Norrbotten. *Geografiska Annaler* 34:1-72.

Howard, E.B. 1935. *Evidence of Early Man in North America: Based on geological and archaeological work in New Mexico*. University of Pennsylvania Museum Journal 24. Philadelphia.

Howard, E.B. (1936a). The antiquity of man in America. *The Scientific Monthly* 43:367-371.

Howard, E.B. (1936b). An outline of the problem of man's antiquity in North America. *American Anthropologist* 38:394-413.

Howard, E.B. (1936c). Early Man in America. *Proceedings of the American Philosophical Society* 76(3):327-333.

Howell, N. (1986). Feedbacks and buffers in relation to scarcity and abundance: studies of hunter-gatherer populations. In *The State of Population Theory: Forward from Malthus*. (D.Coleman and R.Schofield, Eds.), pp. 156-187. Basil Blackwell, Oxford.

Hrdlicka, A. (1918). *Recent discoveries attributed to Early Man in America*. Bureau of American Ethnology Bulletin 66.

Huddleston, L.E. (1967). *Origins of the American Indians: European Concepts, 1492-1729*. University of Texas Press, Austin.

Hughes, O.L. (1972). *Surficial geology of northern Yukon Territory and northwestern District of MacKenzie, N.W.T.* Geological Survey of Canada Paper 69-36, 11p.

Hughes, T. (1987). Ice dynamics and deglaciation models when ice sheets collapsed. In *North America and adjacent oceans during the last deglaciation, The Geology of North America, v. K-3* (W.F. Ruddiman and H.E. Wright, Jr., Eds.), pp. 183-220. Geological Society of America, Boulder, Colorado.

Imbrie, J. and Imbrie, K.P. (1979). Ice Ages: Solving the mystery. Enslow Publishers, Short Hills, New Jersey.

Ingersoll, A.P. (1983). The atmosphere. *Scientific American* 249(3):162-174.

Irving, W.N. (1971). Recent Early Man research in the north. *Arctic Anthropologist* 8(2):68-82.

Ives, J.W. (1977). Pollen separation of the three North American birches. *Arctic and Alpine Research* 9:73-80.

Ives, J.W., Beaudoin, A.B., and Magne, M. (1989a). *Evaluating the role of a Western Corridor in the peopling of the Americas*. Paper prepared for the Circum-Pacific Prehistory Conference. August 2-6, 1989, Seattle, Washington.

Ives, J.W., Beaudoin, A.B., and Magne, M. (1989b). Alberta's western corridor and the peopling of North America. *Canadian Quaternary Association Program and Abstracts*, p.33.

Ives, R.L. (1956). An early speculation concerning the Asiatic origin of the American Indian. *American Antiquity* 21:420-421.

Jackson, L.E., Jr. (1977). Quaternary stratigraphy and terrain inventory, Alberta portion of the Kananaskis Lakes 1:250,000 map sheet (82-J), unpublished Ph.D. thesis, Department of Geology, University of Calgary, 478 p.

Jackson, L.E., Jr., MacDonald, G.M., and Wilson, M.C. (1982). Paraglacial origin for terraced river sediments in Bow Valley, Alberta. *Canadian Journal of Earth Sciences* 19:2219-2231.

Jacobson, G.L. and Bradshaw, R.H.W. (1981). The selection of sites for paleovegetational studies. *Quaternary Research* 16:80-96.

Jarvenpa, R. and Brumbach. (1988). Socio-political organization and decision-making processes: Observations from the Chipewyan. *American Anthropologist* 90:598-618.

Jennings, J.D. (1974). Peopling the New World. In *Prehistory of North America.*, 2nd Edition, pp. 47-70,100-105. McGraw Hill, New York.

Jennings, J.D. (1983) Origins. In *Ancient North America*. (J.Jennings, Ed.), pp. 25-67. W.H. Freeman, San Francisco.

Jewtuchowiz, S. (1968). Accumulation in stagnant ice, with the Spitsbergen Glaciers as Example. *Geographia Polonica* 13:49-56.

Jochim, M. (1983). Optimization models in context. In *Archaeological Hammers and Theories* (A.S. Keene, and J.A. Moore, Eds.), pp. 157-172. Academic Press, New York.

Jochim, M. (1987). Late Pleistocene refugia in Europe. In *The Pleistocene Old World: regional perspectives*. (O. Soffer,Ed.), pp. 317-331. Plenum, New York.

Jochim, M. (1990). The ecosystem concept in archaeology. In *The Ecosystem Approach in Anthropology: From concept to practice*. (E.F. Moran, Ed.), pp. 75-90. University of Michigan Press, Ann Arbor.

Johnson, A.W., and Earle, T. (1987). *The Evolution of Human Societies: from Foraging Group to Agrarian State*. Stanford University Press, Stanford.

Johnson, G.A. (1977). Aspects of regional analysis in archaeology. *Annual Review of Anthropology* 6:479-508.

Johnson, W.H. (1990). Ice-wedge casts and relict patterned ground in central Illinois and their environmental significance. *Quaternary Research* 44:51-72.

Johnston, W.A. (1933). Quaternary geology of North America in relation to the migration of man. In *The American Aborigines* (Diamond Jenness, Ed.), pp. 11-45. University of Toronto Press, Toronto.

Johnston, W.A. and Wickenden, R.T.D. (1931). Moraines and glacial lakes in southern Saskatchewan and southern Alberta, Canada. *Trans. Royal Society of Canada* 25(4):29-44.

Jones, R. (1990). From Kakadu to Kutikina: the southern continent at 18,000 years ago. In *The World at 18,000 B.P. Volume 2. Low Latitudes*. (C. Gamble and O. Soffer, Eds.), pp. 264-295. Unwin Hyman, London.

Kapp, R.O. (1969). *Pollen and spores*. William C. Brown Publishers, Dubuque, Iowa.

Karlstrom, E.T. (1986). Probable ice-wedge casts og Glacier Park, Northwestern Montana. *AMQUA Abstracts*, p. 140.

Keegan, W.F. and Diamond, J.M. (1987). Colonization of islands by humans: A biogeographical perspective. *Advances in Archaeological Method and Theory* 10: 49-91.

Keene, A.S. (1983). Biology, behavior, and borrowing: a critical examination of optimal foraging theory in archaeology. In *Archaeological Hammers and Theories* (A.S. Keene, and J.A. Moore, Eds.), pp. 137-155. Academic Press, New York.

Kelly, R.L. (1983). Hunter-Gatherer mobility strategies. *Journal of Anthropological Research* 39:277-306.

Kelly, R.L. and Todd, L.C. (1988). Coming into the country: early Paleoindian hunting and mobility. *American Antiquity* 53:231-244.

King, F.B. and Graham, R.W. (1981). Effects of ecological and paleoecological patterns on subsistence and paleoenvironmental reconstructions. *American Antiquity* 46: 128-142.

King, G.A. (1985). A standard method for evaluating radiocarbon dates of local deglaciation history of southern Labrador and adjacent Quebec. *Geographie physique et Quaternaire* 39:163-182.

Klassen, R.W. and Vreeken, W.J. (1987). The nature and chronological implications of surface tills and post-till sediments in the Cypress Lake area, Saskatchewan. *Current Research, Part A, GSA Paper 87-1A*, pp. 111-125.

Kozlowski, J.K. (1990). Northern central Europe c. 18,000 B.P. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 204-227. Unwin Hyman, London.

Kukla, G.J. (1975). Missing link between Milankovitch and climate. *Nature* 253:600-603.

Kutzbach, J.E., and Wright, H.E.Jr. (1986). Simulation of the climate of 18,000 yr B.P.: Results for the North American / North Atlantic / European sector. *Quaternary Science Reviews* 4:147-187.

Kvill, D.R. (1985). *The glacial geomorphology of the Brazeau River Valley, Foothills of Alberta*. Unpublished Ph.D. dissertation, University of Alberta.

Kvill, D.R. (1989). Eskers and esker complexes within the foothills portion of the Brazeau River drainage basin. *Canadian Quaternary Association Program and Abstracts*, p. 35.

Lamb, H.H., and Woodroffe, A. (1970). Atmospheric circulation during the last ice age. *Quaternary Research* 1:29-58.

Laughlin, W.S. and Harper, A.B. (1988). Peopling of the continents: Australia and America. In *Biological aspects of human migration*. (C.G.N. Mascie-Taylor and G.W. Lasker, Eds.), pp. 14-40. Cambridge

University Press, Cambridge.

Leach, E. (1973). Concluding address. In *The expectation of culture change*. (C.Renfrew, Ed.), pp. 761-771. Duckworth, London.

Leone, M.P. (1984). *Critical theory in archaeology*. Paper presented in the Department of Anthropology, S.U.N.Y., Binghamton, New York.

Levins, R. (1966). The strategy of model building in population biology. *American Scientist* 54:421-431.

Lichti-Federovich, S. (1970). The pollen stratigraphy of a dated section of Late Pleistocene lake sediment from central Alberta. *Canadian Journal of Earth Sciences* 7:938-945.

Lichti-Federovich, S., and Ritchie, J.C. (1965). Contemporary pollen spectra in central Canada II: the forest-grassland transition in Manitoba. *Pollen et Spores* 7:63-87.

Lichti-Federovich, S., and Ritchie, J.C. (1968). Recent pollen assemblages from the western interior of Canada. *Review of Paleobotany and Palynology* 7:297-344.

Linne, S. (1955). The Bering Isthmus - bridge between Asia and America. *Ethnos* 20:210-215.

Liverman, D.G.E. (1989a). The Laurentide ice sheet in west-central Alberta - Implications for the Ice Free Corridor. *Canadian Quaternary Association Program and Abstracts*, p. 36.

Liverman, D.G.E. (1989b). *The Quaternary geology of the Grande Prairie area, Alberta*. Unpublished Ph.D. dissertation, University of Alberta.

Liverman, D.G.E., Catto, N.R., and Rutter, N.W. (1989). Laurentide glaciation in west-central Alberta: a single (Late Wisconsinan) event. *Canadian Journal of Earth Sciences* 26:266-274.

Locke, W.W. (1990). Late Pleistocene glaciers and the climate of western Montana, U.S.A. *Arctic and Alpine Research* 22(1):1-13.

Longley, R.W. (1972). *The Climate of the Prairie Provinces*. Climatological Studies No. 13, Environment Canada, Toronto,

Lorenz, E.N. (1968). Climatic determinism. *Meteorological Monographs* 8(30):1-10.

Low, B. S. (1990). Human Responses to Environmental Extremeness and Uncertainty: A Cross-Cultural Perspective. In (1990). *Risk and Uncertainty in Tribal and Peasant Economics*. (E. Cashdan, Ed.), pp.

229-255). Westview Press, Boulder, Colorado.

Lowe, J.J., and Walker, M.J.C. (1984). *Reconstructing Quaternary environments*. Longman, London.

Lundquist, J. (1972). Ice-lake types and deglaciation pattern along the Scandinavian mountain range. *Boreas* 1:27-54.

Lynch, T.F. (1991). The peopling of the Americas—A discussion. In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 267-274. CRC Press, Boca Raton, Florida.

MacArthur, R.H. (1972). *Geographical Ecology*. Harper & Row, New York.

MacCluer, J.W., and Dyke, B. (1976). On the minimum size of endogamous populations. *Social Biology* 23:1-12.

MacDonald, G.M. (1982). Late Quaternary paleoenvironments of the Morley Flats and Kananaskis Valley of southwestern Alberta. *Canadian Journal of Earth Sciences* 19:23-35.

MacDonald, G.M. (1987a). Postglacial development of the subalpine-boreal transition forest. *Journal of Ecology* 75:303-320.

MacDonald, G.M. (1987b). Postglacial vegetation history of the Mackenzie River Basin. *Quaternary Research* 28:245-262.

MacDonald, G.M. (1989). Postglacial paleoecology of the subalpine forest-grassland ecotone of southwestern Alberta - New insights on vegetation and climate change in the Canadian Rocky Mountains and adjacent Foothills. *Palaeogeography, Palaeoclimatology, Paleoecology* 73:155-173.

MacDonald, G.M. and Cwynar,L.C. (1985). A fossil pollen reconstruction of the Late Quaternary history of Lodgepole Pine (*Pinus contorta* ssp. *latifolia*) in the Western interior of Canada. *Canadian Journal of Forest Research* 15:1039-1044.

MacDonald, G.M. and J.C. Ritchie. (1986). Modern pollen spectra from the western interior of Canada and the interpretation of late Quaternary vegetation development. *New Phytologist* 103:245-268.

MacDonald, G.M., Beukens, R.P. Kieser, W.E. and Vitt, D.H. (1987). Comparative radiocarbon dating of terrestrial plant macrofossils and aquatic moss from the ice-free corridor of western Canada. *Geology* 15:837-840.

MacGowan, K. (1950). *Early Man in the New World*. MacMillan Company, New York.

MacGowan, K. and Hester, J.H., Jr. (1962). *Early Man in the New World.* 2nd Edition. Doubleday and Co., New York.

MacNeish, R.S. (1959). Men out of Asia: as seen from the northwest Yukon. *University of Alaska Anthropological Papers* Vol. 7:41-70

MacNeish, R.S. (1969). Comment. *Current Anthropology* 10:357.

MacNeish, R.S. (1971). Early man in the Andes. In *Early Man in America.* (R.S. MacNeish, Ed.),pp. 69-79. W.H. Freeman, San Francisco.

MacNeish, R.S., Ed. (1973). *Early Man in America.* Readings from Scientific American. W.H. Freeman, San Francisco.

MacNeish, R.S. (1976). Early Man in the New World. *American Scientist* 64:316-327.

Madeyska, T. (1990). The distribution of human settlement in the extra-tropical Old World 24,000 - 15,000 B.P. In *The World at 18,000 B.P.: Volume 1, High Latitudes.* (O. Soffer and C. Gamble, Eds.), pp. 24-37. Unwin Hyman, London.

Maher, L.J.Jr. (1972). Absolute pollen diagram of Redrock Lake, Boulder County, Colorado. *Quaternary Research* 2:531-533.

Manabe, S. and Broccoli, A.J. (1985). The influence of continental ice sheets on the climate of an ice age. *Journal of Geophysical Research* 90:2167-2190.

Mangerud, J. (1972). Radiocarbon dating of marine shells, including a discussion of apparent age of Recent shells from Norway. *Boreas* 1:143-172.

Manley, G. (1955). A climatological survey of the retreat of the Laurentide ice sheet. *American Journal of Science* 253:256-273.

Markgraf, V., and Lennon, T. (1986). Paleoenvironmental history of the last 13,000 years of the eastern Powder River Basin, Wyoming, and its implications for prehistoric cultural patterns. *Plains Anthropologist* 31:1-12.

Marquardt, W.H. and Crumley, C.L. (1987). Theoretical issues in the analysis of spatial patterning. In *Regional Dynamics: Burgundian Landscapes in Historical Perspective.* (C.L. Crumley and W.H. Marquardt, Eds.), pp. 1-18. Academic Press, San Diego.

Martin, A.C. and Barkley, W.D. (1961). *Seed Identification Manual.* University of California Press, Berkeley.

Martin, M.K. and Voorhies, B. (1975). *Female of the Species*. Columbia University Press, New York.

Martin, P.S. (1973). The discovery of America. *Science* 179:969-974.

Martin, P.S., Quimby, G.I, and Collier, D. (1947). *Indians before Columbus: Twenty thousand years of North American history revealed by archaeology*. University of Chicago Press, Chicago.

Mason, G. (1931). *Columbus Came Late*. The Century Company, New York.

Mason, R.J. (1962). The Paleoindian tradition in eastern North America. *Current Anthropology* 3:227-284.

Mather, J.R. (1954). The effect of climate on the New World migration of primitive man. *Southwestern Journal of Anthropology* 10(3):304-321.

Mathewes, W.H. (1978). Quaternary stratigraphy and geomorphology of Charlie Lake (94 A) map-area, British Columbia. Geological Survey of Canada, Paper 76-20.

Mathewes, W.H. (1980). *Retreat of the last ice sheets in northeastern British Columbia and adjacent Alberta*. Geological Society Canada Bulletin 331.

Matthews, J.V. Jr. (1974). Wisconsin environment of interior Alaska: plant and macrofossil analysis of a 27m core from Isabella Basin (Fairbanks, Alaska). *Canadian Journal of Earth Sciences* 11:828-841.

Matthews, J.V. Jr. (1976). Arctic steppe - An extinct biome. *American Quaternary Association Program and Abstracts*, pp. 73-77.

Matthews, J.V. Jr. (1982). East Beringia during Late Wisconsin time: a review of the biotic evidence. In *Paleoecology of Beringia* (D.M. Hopkins, J.V. Matthews, Jr., C.E. Schweger, and S.B. Young, Eds.). pp. 127-150. Academic Press, New York.

Mattson, L.E. (1990). A comparison of meltwater discharge between a debris free and a debris covered glacier, Canadian Rocky Mountains. *CAG/ACG Annual Meeting Programme and Abstracts*. p. 150.

Mayr, E. (1970). *Populations, Species, and Evolution*. Belknap Press of Harvard University, Cambridge, Mass.

McAndrews, J.H. (1966). Postglacial history of prairie, savanna, and forest of northwestern Minnesota. *Memoirs Torrey Botanical Club* 22.

McAndrews, J.H. (1967). Pollen analysis and vegetational history of the Itasca region, Minnesota. In *Quaternary Paleoecology* (E.J. Cushing and H.E. Wright, Eds.), pp. 219-236. Yale University Press, New Haven.

McAndrews, J.H., and Wright, H.E.Jr. (1969). Modern pollen rain across the Wyoming basins and the northern Great Plains, U.S.A. *Review of Paleobotany and Palynology* 9:17-43.

McArthur, N. (1976). Computer simulations of small populations. *Australian Archaeology Newsletter* 4:53-57.

McCullough, E.J. and Fedirchuk, G.J. (1986). Organizing eastern slopes prehistory: a suggested method. In *Eastern Slopes Prehistory: Selected Papers*. (B. Ronaghan, Ed.), pp. 21-24). Archaeological Survey of Alberta Occasional Paper #30.

Mears, B., Jr. (1981). Periglacial wedges and the Late Pleistocene environment of Wyoming's intermontane basins. *Quaternary Research* 15:171-198.

Mehringer, P.J., Jr., Arno, S.F. and Peterson, K.L. (1977). Postglacial history of Lost Trail Pass Bog, Bitterroot Mountains, Montana. *Arctic and Alpine Research* 9:345-368.

Meiklejohn, C. (1978). Ecological aspects of population size and growth in late glacial and early postglacial northwestern Europe. In *The Early Post-glacial Settlement of Northern Europe*. (P. Mellars, Ed.), pp. 65-80. University of Pittsburgh Press, Pittsburgh.

Meltzer, D.J. (1989). Why don't we know when the first people came to North America? *American Antiquity* 53:471-490.

Meltzer, D.J. and Smith, B.D. (1986). Paleoindian and early Archaic subsistence strategies in Eastern North America. In *Foraging, Collecting, and Harvesting: Archaic Period Subsistence and Settlement in the Eastern Woodlands*. (S. Neusius, Ed.), pp. 3-31. Southern Illinois University at Carbondale Center for Archaeological Investigations Occasional Paper No. 6.

Meltzer, D.J. and Dillehay, T.D. (1991). The problem and the papers.In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 1-9. CRC Press, Boca Raton, Florida.

Mickelson, D.M., Clayton, L., Fullerton, D.S., and Burns, H.W., Jr. (1983). The Late Wisconsin glacial record of the Laurentide Ice Sheet in the U.S. In *Late Quaternary Environments of the U.S. Volume 1. The Late Pleistocene*. (H.E. Wright and S.C. Porter, Eds.), pp. 3-37. University of Minnesota Press, Minneapolis.

Milankovitch, M.M. (1941). *Canon of insolation and the ice-age problem.* Koniglich Serbishe Academie, Beograd. English translation by the Israel Program for Scientific Translations, published for the U.S.

Department of Commerce, and the National Science Foundation, Washington, D.C. (1969).

Milton, K. (1984). Protein and Carbohydrate Resources of the Maku Indians of northwestern Amazonia. *American Anthropologist* 86:7-27.

Minc, L.D., and Smith, K.P. (1989). The spirit of survival: cultural responses to resource variability in North Alaska. In *Bad Year Economics* (P. Halstead and J. O'Shea, Eds.), pp. 8-39. Cambridge University Press, Cambridge.

Mochanov, Y. (1978). Stratigraphy and absolute chronology of the Paleolithic of Northeast Asia. In *Early Man in America from a Circum-Pacific Perspective*. (A.L. Bryan, Ed.), pp. 54-66. University of Alberta Press, Edmonton.

Montet-White, A. (1984). Paleoecology and Paleolithic settlements in the Great Plains of Europe. *Quarterly Review of Archaeology* 5: 14-15.

Montgomery, F.H. (1977). *Seeds and fruits of plants of eastern Canada and northeastern United States*. University of Toronto Press, Toronto.

Moore, C., Ed. (1989). *Peopling the Americas*. Transcript of IDEAS Program, 10/3/89, CBC Transcripts, Montreal.

Moore, J.A. (1981). The effects of information networks in hunter-gatherer societies. In *Hunter-Gatherer Foraging Strategies*. (B. Winterhalder and E.A. Smith, Eds.), pp. 194-217. University of Chicago Press, Chicago.

Moore, P.D., and Webb, J.A. (1978). *An illustrated guide to pollen analysis*. Hodder and Stoughton, London.

Moran, E.F. (1982). *Human Adaptability: An Introduction to Ecological Anthropology*. Westview Press, Boulder.

Moran, E.F. (1990). Ecosystem ecology in biology and anthropology: A critical assessment. In *The Ecosystem Approach in Anthropology: From Concept to Practice*. (E.F. Moran, Ed.), pp. 3-40. University of Michigan Press, Ann Arbor.

Morlan, R.E. (1987). The Pleistocene archaeology of Beringia. In *The Evolution of Human Hunting* (M.H. Nitecki and D.V. Nitecki, Eds.), pp. 267-307. Plenum Press, London.

Mott, R.J. and Jackson, L.E. (1982). An 18,000 year palynological record from the southern Alberta segment of the classical Wisconsinan "ice-free corridor". *Canadian Journal of Earth Sciences* 19:504-513.

Muc, M. (1972). Vascular plant production in the Sedge meadows of the Truelove Lowland. In *Devon Island IBP Project High Arctic Ecosystem Project Report 1970 & 1971*. (L.C. Bliss, Ed.), pp. 113-145. University of Alberta, Edmonton.

Muller-Beck, H. (1966). Paleohunters in America: origins and diffusion. *Science* 152:1191-1210.

Muller-Beck, H. (1967). On migrations of hunters across the Bering Land Bridge in the Upper Pleistocene. In *The Bering Land Bridge* (D.M. Hopkins, Ed.), pp. 373-408. Stanford University Press, Stanford.

Mullineaux, D.R. (1974). *Pumice and other pyroclastic deposits in Mount Rainer National Park, Washington*. United States Geological Survey Bulletin 1326.

Mussi, M. (1990). Continuity and change in Italy at the Last Glacial Maximum. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 127-147. Unwin Hyman, London.

Nambudiri, E.M.V., Teller, J.T., and W.M. Last. (1980). Pre-Quaternary microfossils - A guide to errors in radiocarbon dating. *Geology* 8:123-126.

Nicholson, B.A. (1988). Modeling subsistence strategies in the forest/grassland transition zone of western Manitoba during the Late Prehistoric and Early Historic periods. *Plains* 33:351-365.

Niederland, W.G. (1991). The Naming of America. *In maps from the mind: readings in psychogeography*. (H.F. Stein and W.G. Niederland, Eds.), pp. 82-96. University of Oklahoma Press, Normon.

Nikiforoff, C. (1928). The perpetually frozen subsoil of Siberia. *Soil Science* 26:61-79.

North, M.E.A. (1976). *A plant geography of Alberta*. University of Alberta Studies in Geography Monograph 2.

Odynsky, W. (1958). U-shaped dunes and effective wind directions in Alberta. *Canadian Journal of Earth Sciences* 38:56-62.

Olsen, B. (1990). Comments on 'Archaeology into the 1990's'. *Norwegian Archaeological Review* 22:18-21.

O'Shea, J. and Halstead, P. (1989). Conclusions: bad year economics. In *Bad Year Economics*. (P. Halstead and J. O'Shea, Eds.), pp. 123-126. Cambridge University Press, Cambridge.

Ostrem, G. (1959). Ice melting under a thin layer of moraine, and the existence of ice cores in moraine ridges. *Geografiska Annaler* 41(4):228-

230.

Ostrem, G. (1965). Problems of dating ice-cored moraines. *Geografiska Annaler* 47A:1-38.

Otte, M. (1990). The northwestern European Plain around 18,000 B.P. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 54-68. Unwin Hyman, London.

Pennington, W. (1973). Absolute pollen frequencies in the sediments of lakes of different morphometry. In *Quaternary Plant Ecology*. (H.J.B. Birks and R.G. West, Eds.), pp. 109-115. Wiley, New York.

Perlman, S.M. (1985). Group size and mobility costs. In *The Archaeology of Frontiers and Boundaries*. (S.W. Green and S.M. Perlman, Eds.), pp. 33-50. Academic Press, New York.

Pewe, T.L. (1983). The periglacial environment in North America during Wisconsin time. In *Late Quaternary Environments of the U.S. Volume 1, The Late Pleistocene*. (S.C. Porter, Ed.), pp. 157-189. University of Minnesota Press, Minneapolis.

Phillips, J.L. (1987). Upper Paleolithic hunter-gatherers in the Wadi Feiran Southern Sinai. In *The Pleistocene Old World: regional perspectives*. (O. Soffer, Ed.), pp. 169-182. Plenum, New York.

Porter, S.C. (1988). Landscapes of the last ice age in North America. In *Americans Before Columbus: Ice Age Origins*. (R.C. Carlisle, Ed.), pp. 1-24. University of Pittsburgh, Pittsburgh.

Porter, S.C. and Carson, R.J., III. (1971). Problems of interpreting radiocarbon dates from dead-ice terrain, with an example from the Puget Lowland of Washington. *Quaternary Research* 1:410-414.

Post, A. and Streveler, G. (1976). The Tilted Forest: glaciological-geologic implications of vegetated neoglacial ice at Lituya Bay, Alaska. *Quaternary Research* 6:111-117.

Powers, W.R. (1978). Comments on Paper 'Perspectives on Early Man' *AMQUA Abstracts*, p. 126.

Powers, W.R. and Hoffecker, J.F. (1989). Late Pleistocene settlement in the Nenana Valley, Central Alaska. *American Antiquity* 54:263-287.

Praslov, N.D. (1984). Paleolithic cultures in the Late Pleistocene. In *Late Quaternary Environments of the Soviet Union*. (A.A. Velichko, Ed., H.E. Wright and C.W. Barnosky, Eds., of English language version), pp. 313-318. University of Minnesota Press, Minneapolis.

Prentice, I.C. (1985). Pollen representation, source area, and basin size: Toward a unified theory of pollen analysis. *Quaternary Research* 23:76-86.

Prest, V.K. (1969). Retreat of Wisconsin and Recent Ice in North America. Geological Survey of Canada Map 1257A.

Prest, V.K. (1984). The Late Wisconsinan glacier complex. In *Quaternary Stratigraphy of Canada* (R.J. Fulton, Ed.). Geological Survey of Canada Paper 84-10.

Price, T.D. (1978). Mesolithic settlement systems in the Netherlands. In *The Early Postglacial Settlement of Northern Europe: An Ecological Perspective*. (P. Mellars, Ed.), pp. 81-114. Duckworth, London.

Price, T.D. (1991). The view from Europe: concepts and questions about terminal Pleisticene societies. In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 185-208. CRC Press, Boca Raton, Florida.

Putman, J.J. (1988). The search for modern humans. *National Geographic* 174(4):439-477.

Rainey, F.G. (1940). Archaeological investigations in central Alaska. *American Antiquity* 5:299-308.

Rains, B., Kvill, D., and Shaw, J. (1990). Evidence and some implications of coalescent Cordilleran and Laurentide glacier systems in western Alberta. In *A World of Real Places*. (P.J. Smith and Jackson, E.L., Eds.), pp. 147-161. University of Alberta Press, Edmonton.

Randahl, F.S. (1979). *A prehistory of the U.S. and Canada: An archaeological overview of the population and adaptation in Precolumbian times*. Unpublished Ph.d thesis, Wayne State University.

Reeves, B. (1970). On the coalescence of the Laurentide and Cordilleran ice sheets in the western interior of North America with particular reference to the southern Alberta area. *AMQUA Abstracts*, p. 110.

Reeves, B. (1973). The nature and age of the contact between the Laurentide and Cordilleran ice sheets in the western interior of North America. *Arctic and Alpine Research* 5:1-16.

Reeves, B. (1985). The ice free corridor: A historical perspective. *CANQUA Abstracts*, p. 53.

Reid, J.R., Jr. (1970). Geomorphology and glacial geology of the Martin River Glacier, Alaska. *Arctic* 23:254-267.

Reidhead, V.A. (1979). Linear programming models in archaeology. *Annual Review of Anthropology* 8: 543-578.

Reynolds, T.E.G. and Kamer, S.C. (1990). Japan and Korea at 18,000 B.P. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 296-311. Unwin Hyman, London.

Rickard, W.H. and Vaughn, B.E. (1988). Plant community characteristics and responses. In *Shrub-steppe Balance and Change in a Semi-arid Terrestrial Ecosystem*. (W.H. Rickard, L.E. Rogers, B.E. Vaughn, and S.F. Liebetrau, Eds.), pp. 109-179. Elsevier, New York.

Rigaud, J-P. and Simek, J.F. (1990). The last Pleniglacial in the south of France (24,000 - 14,000 ya). In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 69-86. Unwin Hyman, London.

Ritchie, J.C. (1976). The Late Quaternary vegetational history of the western interior of Canada. *Canadian Journal of Botany* 54:1793-1818.

Ritchie, J.C. (1984). *Past and present vegetation of the far northwest of Canada*. University of Toronto Press, Toronto.

Ritchie, J.C. (1987). *Postglacial Vegetation of Canada*. Cambridge University Press, Cambridge.

Ritchie, J.C. and Lichti-Federovich, S. (1967). Pollen dispersal phenomena in Arctic-Subarctic Canada. *Review of Paleobotany and Palynology* 3:255-266.

Roberts, F.H., Jr. (1940). Developments in the problem of the North American Paleo-Indian. In *Smithsonian Miscellaneous Collections #100. Essays in Historical Anthropology of North America*. pp. 51-116.

Roed, M.A. (1975). Cordilleran and Laurentide multiple glaciation, west-central Alberta, Canada. *Canadian Journal of Earth Sciences* 12:1493-1515.

Rogers, E.S. (1969). Natural Environment - Social Organization - Witchcraft: Cree Versus Ojibwa - A Test Case. *National Museum of Canada Bulletin* No. 230, Anthropology Series No. 86, pp. 24-39.

Rogers, L.E., Fitzner, R.E., Caldwell, L.L., and Vaughn, B.E. (1988). Terrestrial animal habitats and population responses. In *Shrub-steppe Balance and Change in a Semi-arid Terrestrial Ecosystem*. (W.H. Rickard, L.E. Rogers, B.E. Vaughn, and S.F. Liebetrau, Eds.), pp. 181-256. Elsevier, New York.

Rouse, I. (1976). Peopling of the Americas. *Quaternary Research* 6:597-612.

Rowe, J.S. (1972). *Forest regions of Canada*. Canadian Forest Service Publication 1300.

Rowley-Conwy, P. and Zvelebil, M. (1989). Saving it for later: storage by prehistoric hunter-gatherers in Europe. In *Bad Year Economics*. (P. Halstead and J. O'Shea, Eds.), pp. 40-56. Cambridge University Press, Cambridge.

Ruddiman, W.F. (1987). Synthesis: the ocean/ice sheet record. In *North America and Adjacent Oceans During the Last Glaciation, Geology of North America Volume K-3*. (W.F. Ruddiman and H.E. Wright, Eds.), pp. 463-478. Geological Society of America, Boulder.

Ruddiman, W.F. and McIntyre, A. (1981). The mode and mechanism of the last deglaciation: Oceanic evidence. *Quaternary Research* 16:125-134.

Ruddiman, W.F. and Wright, H.E., Jr. (1987). Introduction. In *North America and adjacent oceans during the last deglaciation, The Geology of North America, v. K-3* (W.F. Ruddiman and H.E. Wright, Jr., Eds.), pp. 1-12. Geological Society of America, Boulder, Colorado.

Russell, I.C. (1893). Malaspina Glacier. *Journal of Geology* 1:217-245.

Russell, D.E. and Martell, A.M. (1984). Winter range ecology of Caribou (*Rangifer tarandus*). In *Northern Ecology and Resource Management: Memorial Essays Honoring Don Gill*. (R. Olson, R. Hastings, and F. Geddes, Eds.), pp. 117-144. University of Alberta Press, Edmonton.

Rutter, N.W. (1978). Geology of the ice-free corridor. *AMQUA Abstracts*, pp. 2-9.

Rutter, N.W. (1980). Late Pleistocene history of the western Canadian ice-free corridor. *Canadian Journal of Anthropology* 1(1):1-8.

Rutter, N.W. (1984). Pleistocene history of the western Canadian ice-free corridor. In *Quaternary Stratigraphy of Canada* — A Canadian contribution to IGCP Project 24 (R.J. Fulton, Ed.), pp. 49-56. Geological Survey of Canada Paper 84-10.

Rutter, N.W. and Schweger, C.E., Eds. (1980). The Ice Free Corridor and Peopling of the New World. Proceedings of the Fifth Biennial Conference of the American Quaternary Association. *Canadian Journal of Anthropology* 1.

Said, E. (1978). *Orientalism*. Routledge & Kegan Paul, London.

St. Onge, D.A. (1972). *Sequence of glacial lakes in north-central Alberta*. Geological Survey of Canada Bulletin 213.

Sauer, C.O. (1944). A geographic sketch of Early Man in America. *Geographical Review* 34:529-573.

Sauer, C.O. (1957). The end of the ice-age and it's witnesses. *Geographical Review* 47:29-43.

Savage, S.H. (1990a). GIS in archaeological research. In *Interpreting Space: GIS and Archaeology*. (K.M.S. Allen, S.W. Green, and E.B.W. Zubrow, Eds.), pp. 22-32. Taylor and Francis, London.

Savage, S.H. (1990b). Modeling the Late Archaic social landscape. In *Interpreting Space: GIS and Archaeology*. (K.M.S. Allen, S.W. Green, and E.B.W. Zubrow, Eds.), pp. 330-355. Taylor and Francis, London.

Schmider, B. (1990). The last Pleniglacial in the Paris Basin (22,500 - 17,000 B.P.). In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 41-53. Unwin Hyman, London.

Schneider, S.H. (1972). Cloudiness as a global climatic feedback mechanism: The effects on the radiation balance and surface temperature of variations in cloudiness. *Journal of the Atmospheric Sciences* 29:1413-1422.

Schweger, C.E. (1976). *Late Quaternary paleoecology of the Onion Portage region, northwestern Alaska*. Unpublished Ph.D. thesis, Department of Geology, University of Alberta, Edmonton.

Schweger, C.E. (1982). Late Pleistocene vegetation of Eastern Beringia: Pollen analysis of dated alluvium. In *Paleoecology of Beringia* (D.M. Hopkins, J.V. Matthews, Jr., C.E. Schweger, and S.B. Young, Eds.). pp. 95-112. Academic Press, New York.

Schweger, C.E. (1985). A 24,00 year pollen record from Goldeye Lake, Alberta - Implications to the paleoecology of the ice-free corridor. *Canadian Quaternary Association Program with Abstracts and Field Guide*, p. 55.

Schweger, C.E., and Habgood, T. (1976). The late-Pleistocene steppe-tundra of Beringia - a critique. *American Quaternary Association Program and Abstracts*, pp. 80-81.

Schweger, C.E., Habgood, T., and Hickman, M. (1981). Late glacial-Holocene climatic changes in Alberta. The record from sediment studies. In *The impact of climatic fluctuations on Alberta's resources and environment*. (K.D. Leggat and J.T. Kotylak, Eds.), pp. 47-59. Atmospheric Environment Service, Western Region, Environment Canada, Edmonton, Alberta Report No. WAES-1-81.

Schweger, C.E. and Hickman, M. (1989). Holocene paleohydrology of central Alberta: testing the general-circulation-model climate simulations. *Canadian Journal of Earth Sciences* 26:1826-1833.

Schweger, C.E., Matthews, J.V.Jr., Hopkins, D.M., and Young, S.B. (1982). Paleoecology of Beringia — A Synthesis. In *Paleoecology of Beringia* (D.M. Hopkins, J.V. Matthews, Jr., C.E. Schweger, and S.B. Young, Eds.). pp. 425-444. Academic Press, New York.

Sellards, E.H. (1952). *Early Man in America: A study in Prehistory*. University of Texas Press, Austin.

Shanks, M. and Tilley, C. (1989). Archaeology into the 1990's. *Norwegian Archaeological Review* 22(1):1-12.

Sharp, R.P. (1949). Studies of superglacial debris on valley glaciers. *American Journal of Science* 247(5):289-315.

Sharp, R.P. (1951). Glacial history of Wolf Creek, St. Elias Range, Canada. *Journal of Geology* 59:97-116.

Sharp, R.P. (1958). The latest major advance of the Malaspina Glacier, Alaska. *Geographical Review* 48:16-26.

Shetsen, I. (1987). Quaternary Geology Southern Alberta (Map), Alberta Research Council 1:500,000.

Shetsen,I. (1990). Quaternary Geology, Central Alberta (Map) Alberta Research Council, 1:500,000.

Shotton, F.W. (1972). An example of hard-water error in radiocarbon dating of vegetable matter. *Nature* 240:460-461.

Shutler, R. (1971). Introduction: Papers from a symposium on Early Man in North America, New Developments: 1960-1970. *Arctic Anthropology* 8(2):1-2.

Slater, D.S. (1985). Pollen analysis of postglacial sediments from Eildon Lake, District of Mackenzie, N.W.T., Canada. *Canadian Journal of Earth Sciences* 22:663-674.

Smith, M.A. (1987). Pleistocene occupation in arid central Australia. *Nature* 328:710-711.

Smith, P.S. (1937). Certain relations between Northwestern North America and Northeastern Asia. In *Early Man*. (GG.G. MacCurdy, Ed.), pp. 85-92. J.B. Lippincott, Philadelphia.

Snow, D. (1981). Approaches to cultural adaptation in the Northeast. In

Foundations of Northeast Archaeology (D. Snow, Ed.), pp. 95-138.

Soffer, O. (1985). *The Upper Paleolithic of the Central Russian Plain*. Academic Press, New York.

Soffer, O. (1987). Upper Paleolithic connubia, refugia, and the archaeological record from Eastern Europe. In *The Pleistocene Old World: regional perspectives*. (O. Soffer, Ed.), pp. 333-348. Plenum, New York.

Soffer, O. (1990). The Russian Plain at the Last Glacial Maximum. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 228-252. Unwin Hyman, London.

Solomon, A.M., and Silkworth, A.B. (1986). Spatial patterns of atmospheric transport in a montane region. *Quaternary Research* 25:150-162.

Spaulding, W.G., Leopold, E.B., and VanDevenfer, T.R. (1983). Late Wisconsin paleoecology of the American southwest. In *Late Quaternary of the United States, Vol. 1*. (S.C. Porter, Ed.), pp. 259-293. University of Minnesota Press, Minneapolis.

Speight, R. (1940). Ice wastage and glacier retreat in New Zealand. *Journal of Geomorphology* 3:131-143.

Spencer, R.F. and Jennings, J.D. (1965). *The Native Americans*. Harper and Row, New York.

Speth, J.D. and Spielmann, K.A. (1983). Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *Journal of Anthropological Archaeology* 2:1-31.

Spinden, H.J. (1933). Origin of civilizations in Central America and Mexico. In *The American Aborigines* (Diamond Jennness, Ed.), pp. 219-224. University of Toronto Press, Toronto.

Stalker, A. Macs. (1956). *The Erratics Train Foothills of Alberta*. Geological Survey of Canada Bulletin 37.

Stalker, A. MacS. (1960). *Ice-pressed drift forms and associated deposits in Alberta*. Geological Survey of Canada Bulletin 57.

Stalker, A. MacS. (1970). Late Wisconsin glaciation and the Yukon-Alberta ice free corridor. *AMQUA Abstracts*, p. 126.

Stalker, A. MacS. (1977). Indications of Wisconsin and earlier man from the southwest Canadian Prairies. *Annals of the New York Academy of Sciences* 288:119-136.

Stalker, A. MacS. (1978). The geology of the ice free corridor: the southern half. *AMQUA Abstracts*, pp. 19-22.

Stalker, A. MacS. and Harrison, J.E. (1977). The Quaternary glaciation of the Waterton-Castle River region of Alberta. *Canadian Petroleum Geology Bulletin* 25:882-896.

Stephens, F.R. (1969). A forest ecosystem on a glacier in Alaska. *Arctic* 22:441-444.

Steward, J. (1955). Theory of Culture Change. University of Illinois Press, Urbana.

Stewart, T.D. (1949). The development of the concept of morphological dating in connection with Early Man in America. *Southwestern Journal of Anthropology* 5:1-16.

Stockmaar, J. (1972). Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13:615-621.

Straus, L.G. (1990). The Last Glacial Maximum in Cantabrian Spain: The Solutrean. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 89-108. Unwin Hyman, London.

Sugden, D.E. and John, B.S. (1976). *Glaciers and Landscapes: A geomorphological approach*. Edward Arnold, London.

Svoboda, J. (1972). Vascular plant productivity studies of raised beach ridges (Semi-polar desert) in the Truelove Lowland. In *Devon Island IBP Project High Arctic Ecosystem Project Report 1970-71*. (L.C. Bliss, Ed.), pp. 146-184. University of Alberta, Edmonton.

Svoboda, J. (1990). Moravia during the Upper Pleniglacial. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 193-203. Unwin Hyman, London.

Teller, J.T. (1989). Importance of the Rossendale Site in establishing a deglacial chronology along the southwestern margin of the Laurentide ice sheet. *Quaternary Research* 32:12-23.

Terasmae, J. (1973). Notes on Late Wisconsin and Early Holocene history of vegetation in Canada. *Arctic and Alpine Research* 5:201-222.

Thomas, D.H. (1989). *Archaeology*. 2nd Edition. Holt, Rinehart and Winston, Inc., Chicago.

Thomas, D.S.G. (1989). *Arid Zone Geomorphology*. Halstad Press, New York.

Thorpe, F.N. (1905). *The history of North America*. George Barrie and Sons, Philadelphia.

Tolstoy, P. (1975). From the Old World to the New World via Bering Straight. In *North America* (S. Gorenstein, Ed.), pp. 165-180. St. Martin's Press, New York.

Trigger, B. (1986). Prehistoric archaeology and American society. In *American archaeology: Past and Future*. (D.J. Meltzer, D.D. Fowler and J.A. Sabloff, Eds.), pp. 187-215. Smithsonian Institution Press, Washington, D.C.

Turner, A. (1984). Hominids and fellow travelers: Human migration into high latitudes as part of a large mammal community. In *Hominid Evolution and Community Ecology*. (R.E. Foley, Ed.), pp. 193-217. Academic Press, New York.

Turner, J.V., Fritz, P., Karrow, P.F. and Warner, B.G. (1983). Isotopic and geochemical composition of marl lake waters and implications for radiocarbon dating of marl lake sediments. *Canadian Journal of Earth Sciences* 20:599-615.

Tyrrell, J.B. (1890). Post-Tertiary deposits of Manitoba and the adjoining territories of northwestern Canada. *Geological Society of America Bulletin* 1:393-410.

Upham, W. (1896). *The Glacial Lake Agassiz*. U.S.G.S. Monograph No. 25.

Vance, R.E. (1986a). Late Quaternary vegetation and climate of the eastern slopes - the record from pollen studies. *Archaeological Survey of Alberta Occasional Paper* 30:247-267.

Vance, R.E. (1986b). Pollen stratigraphy of Eaglenest Lake, northeastern Alberta. *Canadian Journal of Earth Sciences* 23:11-20.

Velichko, A.A. and Kurenkova, E.I. (1990). Environmental conditions and human occupation of northern Eurasia during the Late Valdai. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 255-265. Unwin Hyman, London.

Waddington, J.C.B., and Wright, H.E.Jr. (1974). Late Quaternary vegetational changes on the east side of Yellowstone Park, Wyoming. *Quaternary Research* 4:175-184.

Walter, H. (1979). *Vegetation of the earth and ecological systems of the geo-biosphere*. Springer-Verlage, New York.

Watson, P.J., LeBlanc, S.A., and Redman, C.L. (1984). *Archaeological Explanation: The Scientific Method in Archaeology*. Columbia

University Press, New York.

Wedel, W.R. (1961). *Prehistoric Man on the Great Plains*. University of Oklahoma Press, Norman.

Weiss, K.M., Ferrell, R.E., and Harris, C.L. (1984). A New World syndrome of metabolic diseases with a genetic and evolutionary basis. *Yearbook of Physical Anthropology* 27:153-178.

Wells, G.L. (1983). Late-glacial circulation over central North America revealed by aeolian features. In *Variations in the Global Water Budget*. (A. Street-Perrott, M. Beran, and R. Ratcliff, Eds.), pp. 317-330. Reidel, Boston.

Wendorf, F. (1966). Early Man in the New World: Problems of migration. *The American Naturalist* 100:253-270.

Wendorf, M. (1989). Diabetes, the Ice Free Corridor, and the Paleoindian settlement of North America. *American Journal of Physical Anthropology* 79:503-520.

Weniger, G-C. (1990). Germany at 18,000 B.P. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 171-192. Unwin Hyman, London.

Wenke, R.J. (1989). Comments on 'Archaeology into the 1990's'. *Norwegian Archaeological Review* 22:31-33.

Westgate, J.A. (1969). The Quaternary Geology of the Edmonton Area. In *Pedology and Quaternary Research*. (S. Pawluk, Ed.), pp. 129-151. University of Alberta, Edmonton.

Wetzel, R.E. (1970). Recent and postglacial production rates of a marl lake. *Limnology and Oceanography* 15:491-503.

White, J.M. and Mathewes, R.W. (1986). Postglacial vegetation and climatic change in the Upper Peace River District, Alberta. *Canadian Journal of Botany* 64:2305-2318.

White, J.M., Mathewes, R.W., and Mathews, W.H. (1985). Late Pleistocene chronology and environment of the 'ice-free corridor' of northwestern Alberta. *Quaternary Research* 24:173-186.

White, J.P. and O'Connell, J. (1982). *A Prehistory of Australia, New Guinea, and Sahul*. Academic Press, Sydney.

White, R. (1985). *Upper Paleolithic Land Use in the Perigord: A Topographic Approach to Subsistence and Settlement*. BAR International Series 253, Oxford.

Whiteside, M.C., Bradbury, J.P. and Tarapchak. (1980). Limnology of the Klutan Moraines, Yukon Territory, Canada. *Quaternary Research* 14:130-148.

Whiting, J.W.M., Sodergren, J.A., and Stigler, S.M. (1982). Winter temperatures as a constraint to the migration of Preindustrial peoples. *American Anthropologist* 84:279-298.

Whittaker, R.H. and Likens, G.E. (1975). The biosphere and man. In *Primary Productivity of the Biosphere*. (H. Lieth and R.H. Whittaker, Eds.), pp. 305-328. Springer-Verlag, New York.

Whynne-Hammond, Charles. (1985). *Elements of Human Geography*. Second Edition. George, Allen and Unwin, London.

Wilson, I. (1986). *The Pink Mountain Site (HhRr 1): Archaeological assessment and monitoring of an early man site in northeastern, British Columbia*. Report on file, British Columbia Heritage Branch, Victoria, British Columbia.

Wilson, I. (1987). The Pink Mountain Paleo-Indian Site. In *Archaeology in Alberta, 1986*. (M. Magne, Ed.), pp. 217-219. Archaeological Survey of Alberta Occasional Paper 31. Alberta Culture and Multiculturalism, Edmonton.

Wilson, M.C. (1990). Archaeological geology in western Canada; techniques, approaches and integrative themes. In *Archaeological Geology of North America*. (N.P. Lasca and J. Donahue, Eds.), pp. 61-86. Geological Society of America Centennial Special Volume 4, Boulder.

Wilson, M.C. and Churcher, C.S. (1978). Late Pleistocene *Camelops* from the Gallelli Pit, Calgary, Alberta: Morphology and Geological Setting. *Canadian Journal of Earth Sciences* 15:729-740.

Winterhalder, B. (1986). Diet choice, risk, and food sharing in a stochastic environment. *Journal of Anthropological Archaeology* 5: 369-392.

Winterhalder, B.W., Baillargeon, W., Cappelletto, F., Daniel, I.R., Jr., and Prescott, C. (1988). The population ecology of hunter-gathers and their prey. *Journal of Anthropological Archaeology* 7:289-328.

Winters, H.A. (1961). Landforms associated with stagnant glacial ice. *The Professional Geographer* 13(4):19-23.

Wissler, C. (1933). Ethnological Diversity in America and its significance. In *The American Aborigines* (Diamond Jenness, Ed.), pp. 167-216. University of Toronto Press, Toronto.

Wobst, H.M. (1974). Boundary Conditions for Paleolithic social systems: a simulation approach. *American Antiquity* 39: 147-178.

Wobst, H.M. (1976). Locational relationships in Paleolithic society. *Journal of Human Evolution* 5:49-58.

Wobst, H.M. (1990). Afterword: Minitime and megaspace in the Palaeolithic at 18K and otherwise. In *The World at 18,000 B.P.: Volume 1, High Latitudes*. (O. Soffer and C. Gamble, Eds.), pp. 331-343. Unwin Hyman, London.

Wood, W.R. and Johnson, D.L. (1978). A survey of disturbance processes in archaeological site formation. In *Advances in Archaeological Method and Theory Vol. 1* (M.B. Schiffer, Ed.), pp. 315-383. Academic Press, New York.

Wormington, H.M. (1957). *Ancient Man in North America*. 7th Edition. Denver Museum of Natural History Popular Series No. 4.

Wright, G.F. (1893). *Man and the Glacial Period*. Appleton and Co., New York.

Wright, G.F. (1914). *The Quaternary Ice Age*. MacMillan and Co., London.

Wright, H.E., Jr. (1967). A square-rod piston sampler for lake sediments. *Journal of Sedimentary Petrology* 37:975-976.

Wright, H.E., Jr. (1971). Late Quaternary vegetational history of North America. In *The Late Cenezoic Glacial Ages*. (K.K. Turekian, Ed.), pp. 425-464. Yale University Press, New Haven.

Wright, H.E., Jr. (1980). Surge moraines of the Klutan Glacier, Yukon Territory, Canada: Origin, wastage, vegetation succession, lake development and application to the Late Glacial of Minnesota. *Quaternary Research* 14:2-18.

Wright, H.E., Jr. (1987). Synthesis: Land south of the ice sheets. In *North America and Adjacent Oceans during the Last Glaciation, Geology of North America Volume K-3*. (W.F. Ruddiman and H.E. Wright, Eds.), pp. 479-488. Geological Society of America, Boulder.

Wright, H.E., Jr. (1991). Environmental conditions for Paleoindian immigration. In *The First Americans: Search and Research* (T.D. Dillehay and D.J. Meltzer, Eds.), pp. 113-135. CRC Press, Boca Raton, Florida.

Wright, H.E., Jr., Almendinger, J.C., and Gruger, J. (1985). Pollen diagram from the Nebraska Sandhills and the age of the dunes. *Quaternary Research* 24:115-120.

Young, M. and Bradley, R.S. (1984). Insolation gradients and the paleoclimatic record. In *Milankovitch and climate, Part 2*. (A.L. Berger, J. Imbrie, J. Hays, G. Kukla, and B. Saltzman, Eds.), pp. 707-713. D. Reidel, Dordrecht.

Young, R.R., Burns, J.A., Rains, R.B., Buekens, R.P., and Kieser, W.E. (1989). Laurentide dynamics and chronology in south-central Alberta. *Canadian Quaternary Association Program and Abstracts*, p. 51.

Young, R., Burns, J., Rains, R.B., Buekens, R., and Kieser, W. (1990). A proposed style of glaciation in Alberta. *CAG/ACG Annual Meeting Programme and Abstracts*. p. 194.

Young, S.B. (1976). Is Steppe Tundra alive and well in Alaska? *American Quaternary Association Program and Abstracts*, pp. 84-88.

Young, S.B. (1988). Beringia: an ice age view. In *Crossroads of Continents: Cultures of Siberia and Alaska*. C.W. Fitzhugh and A. Cromwell, Eds.), pp. 106-110. Smithsonian Institution Press, Washington, D.C.

Zoltai, S.C. and Vitt, D.H. (1990). Holocene climatic change and the distribution of peatlands in western interior Canada. *Quaternary Research* 33:231-240.

Zutter, C. (1987). *Predicting North American Late Pleistocene archaeology using an Optimal Foraging approach*. Unpublished Anthropology Honor's Thesis, University of California.

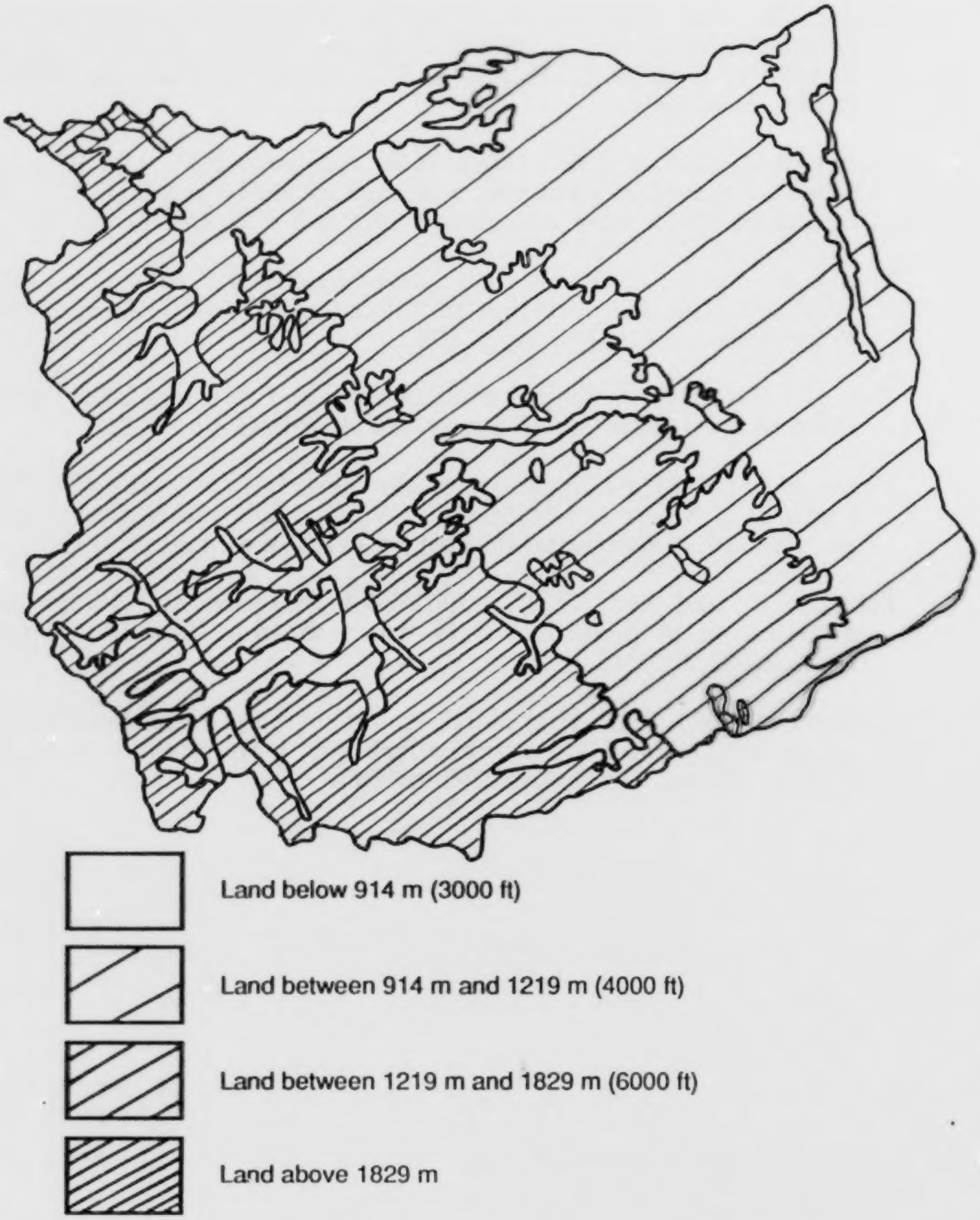

Land below 914 m (3000 ft)
Land between 914 m and 1219 m (4000 ft)
Land between 1219 m and 1829 m (6000 ft)
Land above 1829 m

Figure 7.5a Topographic Map of the Upper North Saskatchewan Drainage Basin (Overlay)